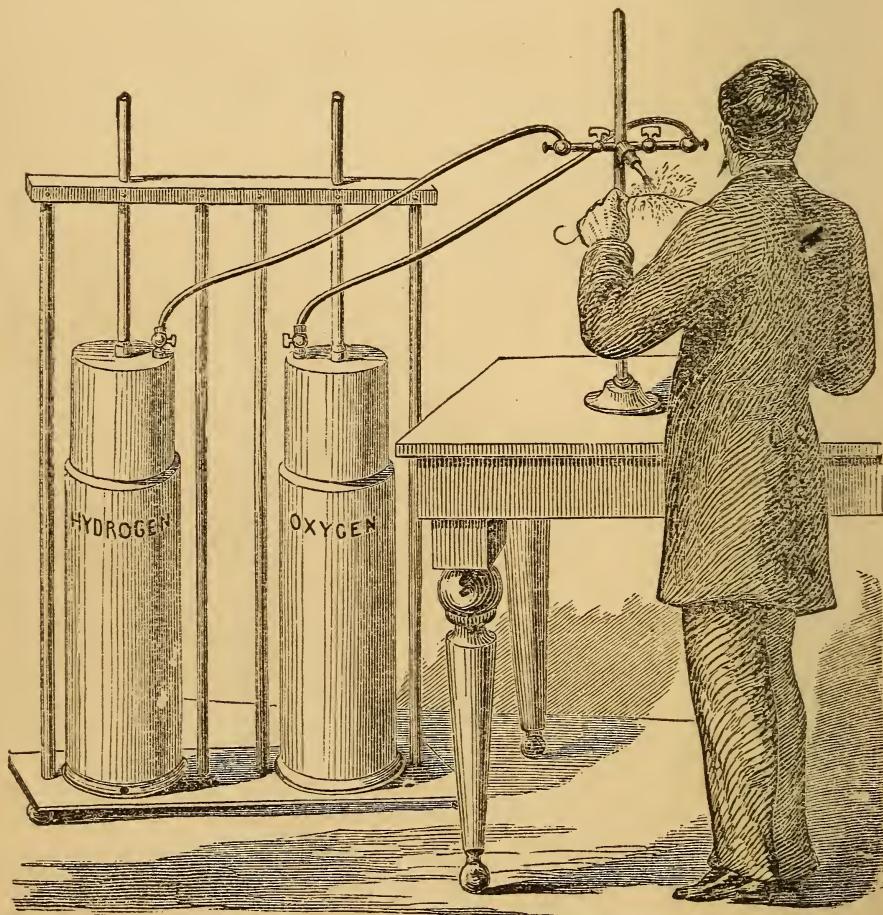




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OXYHYDROGEN BLOW-PIPE.

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A

FOURTEEN WEEKS COURSE IN CHEMISTRY.

BY

J. DORMAN STEELE, A. M.,
PRINCIPAL OF ELMIRA FREE ACADEMY,

"Bright and glorious is that revelation
Written all over this great world of ours."

LONGFELLOW.

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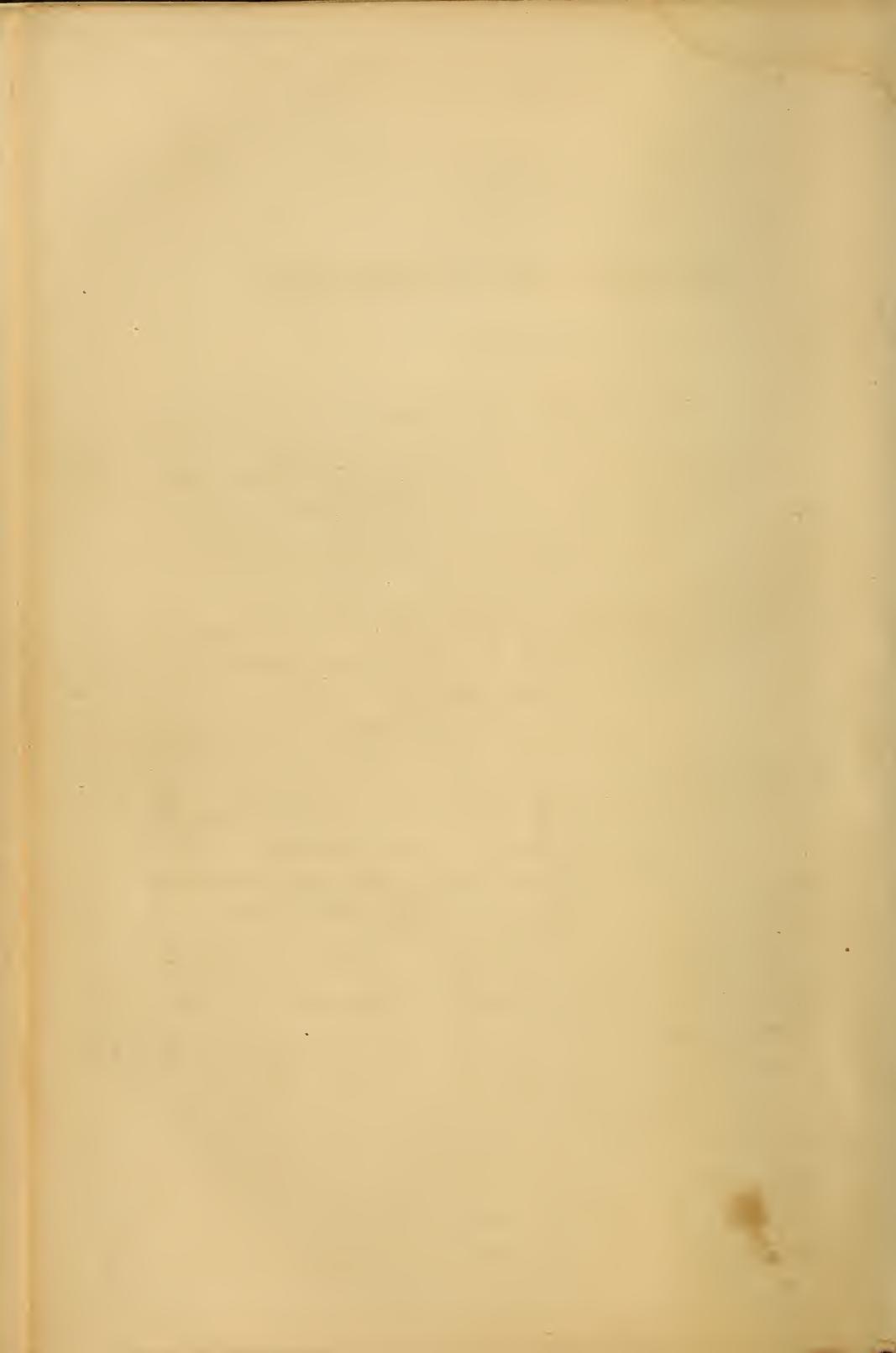
P R E F A C E.

In the preparation of this little volume the author lays no claim to originality: his has been the far humbler task of endeavoring to express, in simple, interesting language, a few of the principles and practical applications of Chemistry. There is a large class of pupils in our schools who can pursue this branch only a single term, the time assigned to it in most institutions. They do not intend to become chemists, nor even professional students. If they wander through a large text-book, they become confused by the multiplicity of strange terms, which they cannot tarry to master, and, as the result, too often only "see men as trees walking." Attempts have been made to reach this class by omitting or disguising the nomenclature; but this robs the science of its mathematical beauty and discipline, while it does not fit the student to read other chemical works or to understand their formulæ. The author has tried to meet this want by omitting that which is perfectly obvious to the eye—that which everybody already knows—that which could not be long retained in the memory—and that which is essential

only to the chemist. He has not attempted to make a reference-book, lest the untrained mind of the learner should become clogged and wearied with a multitude of detail. He has sought to make a pleasant study which the pupil can master in a single term, so that all its truths may become to him "household words." Botany, Natural Philosophy, and Physiology are omitted, since they are now pursued as separate branches. Unusual importance is given to that practical part of chemical knowledge which concerns our every-day life, in the hope of bringing the school-room, the kitchen, the farm, and the shop in closer relationship. This work is designed for the instruction of youth, and for their sake clearness and simplicity have been preferred to recordite accuracy. If to some young man or woman this becomes the opening door to the grander temple of Nature beyond, the author will be abundantly repaid for all his toil.

SUGGESTIONS TO TEACHERS.

IT is recommended that in the use of this book the topical method of recitation should be adopted. So far as possible, the order of the subjects is uniform—viz., Source, Preparation, Properties, Uses, etc. The subject of each paragraph indicates a question which should draw from the pupil all the substance of what follows. At each recitation the scholar should be prepared to explain any point passed over during the term, upon its title being given by the teacher. Such reviews at every recitation are of incalculable value. While some are reciting, let others write upon certain topics at the blackboard, and let the class criticise the thought, the language, the spelling, and the punctuation. Let each pupil keep a lecture-book, in which to record under each general head of the text-book all the experiments, descriptions, and general information given by the teacher in class. In order to accustom the scholar to the nomenclature, use the symbols constantly from the beginning: they may seem dull at first, but if every compound be thus named, a familiarity with chemical language will be induced that will be as pleasing as it will be profitable. If time will admit, in addition, have weekly essays prepared by the class, combining information from every attainable source.



ELEMENTARY CHEMISTRY.

INTRODUCTION.

CHEMISTRY treats of the *specific* properties of matter and the composition of bodies. Examples: gold is yellow; water is composed of two gases, hydrogen and oxygen.

ORGANIC CHEMISTRY deals with those substances that have been produced by life. Examples: flesh, wood. INORGANIC CHEMISTRY is confined to those bodies that have not been formed by life. Examples: metals, rocks.

An ELEMENT is a kind of matter which has never been separated into anything else. Examples: silver, iron. There are about 65 in all, of which 52 are metals, and 13 metalloids or non-metallic substances.

CHEMICAL AFFINITY is that force that causes the elements of matter to unite and form new compounds. It acts at distances so slight as to be insensible, and upon the most dissimilar substances: the more dissimilar the stronger the union. Example: a little chlorate of potassa and sulphur mixed in a mortar will not combine, but a slight pressure of the pestle will bring them within the range of attraction, and they will burn with a loud explosion.

Nothing in the nature or appearance of any element indicates its chemical affinity. We can only tell by trial with what it will combine. This attraction is not a mere freak of nature, but a law stamped upon matter by God himself for wise and beneficent purposes.

COMPOUNDS are utterly unlike their elements in all their properties. Examples: yellow sulphur and white quicksilver form red vermillion; the inert nitrogen and the oxygen of the air constitute a corrosive acid—*aqua fortis*; charcoal, hydrogen, and nitrogen produce the deadly prussic acid; solid charcoal and sulphur make a colorless liquid; poisonous and offensive chlorine combines with the brilliant metal sodium to form common salt.

HEAT and LIGHT favor chemical action, and frequently develop an affinity where it seemed to be wanting. The former especially, by its expansive force, tends to drive the elements of a compound without the range of old attractions and within that of new ones. Examples: gun-cotton, when lying in the air, is apparently harmless, but a spark of fire will produce a brilliant flash, and it disappears as a gas: nitrate of silver turns black in the sun, by the action of the light.

SOLUTION also aids in chemical change, as it destroys cohesion and leaves the atoms free to unite. Example: carbonate of soda and tartaric acid mixed in a glass will not combine, but a little water added will produce a violent effervescence.

The CHEMICAL EQUIVALENT of an element is the

proportion by weight in which it unites with other elements. There is no chance-work in nature. No matter under what circumstances a compound is formed, the proportion of its elements is the same. Example : the carbonic acid produced amid the roar of a conflagration or the explosion of a volcano is identical with that made in the quiet burning of a match.

The ATOMIC THEORY, which lies at the basis of chemistry, as now understood, supposes—

1st. That bodies are composed of individual and unchangeable atoms.

2d. That the chemical equivalent represents the relative weight of the atoms of different kinds.

3d. That compounds are formed by the union of different kinds of atoms in the proportion of their equivalents, or multiples of their equivalents.

4th. That the chemical equivalent of a compound is equal to the sum of the chemical equivalents of its elements.

NOMENCLATURE.—The elements which were known anciently have retained their names. Those discovered more recently are named from some peculiarity. Examples : chlorine, from its green color ; bromine, from its bad odor. Of late the uniform termination *um* has been adopted.

SYMBOLS.—The first letter of the English name has been taken as the symbol. When that would produce confusion, the Latin name has been substituted, and in some cases the second letter added. Examples : carbon and chlorine both commence with

C; so the latter takes Cl for its symbol. Silver and silicon both begin with Si, hence the former assumes Ag, from its Latin name, Argentum. If more than one equivalent of an element is used in forming a compound, this is shown by writing the number below the symbol. Example : O₂ indicates two equivalents of O. In the use of the following table, the symbol should recall, not the name of the element alone, but the relative weight of its atoms. Example : O means 8 parts of oxygen by weight.

TABLE OF ELEMENTS AND EQUIVALENTS.

ELEMENTS.	Symbol.	Equivalent.	ELEMENTS.	Symbol.	Equivalent.
Aluminum,	Al.	13.70	Niobium (Columbi-	Nb.	48.80
-Antimony (Stibium),	Sb.	129.00	um),	N.	14.00
-Arsenicum,	As.	75.00	Nitrogen,	No.	
-Barium,	Ba.	68.50	Norium,	Os.	99.40
-Bismuth,	Bi.	210.30	Osmium,	O.	8.00
-Boron,	Bo.	10.90	Oxygen,	Pd.	53.20
-Bromine,	Br.	80.00	Palladium,	P.	31.00
-Cadmium,	Cd.	56.00	Phosphorus,	Pt.	98.60
-Cæsium,	Cs.	123.40	Platinum,	K.	39.00
-Calcium,	Ca.	20.00	Potassium (Kalium),	Rh.	53.20
-Carbon,	C.	6.00	Rodium,	Ru.	85.36
-Cerium,	Ce.	46.00	Ruthenium,	Se.	52.11
-Chlorine,	Cl.	35.50	Selenium,	Si.	39.70
-Chromium,	Cr.	26.30	Silicon,	Ag.	14.00
-Cobalt,	Co.	29.50	Silver (Argentum),	Na.	108.00
-Copper (Cuprum)	Cu.	31.70	Sodium (Natrium),	Sr.	23.00
-Didymium,	D.	48.00	Strontrium,	S.	43.80
-Erbium,	E.		Sulphur,	Ta.	16.00
-Fluorine,	F.	19.00	Tantalum,	Te.	68.80
-Glucinum,	Gl.	4.70	Tellurium,	Tb.	64.50
-Gold (Aurum),	Au.	196.44	Terbium,	Tl.	
-Hydrogen,	H.	1.00	Thallium,	Th.	
-Iodine,	I.	127.00	Thorinium,	Ta.	
-Iridium,	Ir.	98.60	Tin (Stannum),	Sn.	59.50
-Iron (Ferrum),	Fe.	28.00	Titanium,	Ti.	59.00
-Lanthanum,	La.	46.00	Tungsten (Wol-	W.	25.00
-Lead (Plumbum),	Pb.	103.60	fram),	U.	92.00
-Lithium,	L.	7.00	Uranium,	V.	60.00
-Magnesium,	Mg.	12.16	Vanadium,	Y.	68.50
-Manganese,	Mn.	27.48	Yttrium,	Zn.	
-Mercury (Hydrargy-	Hg.	100.00	Zinc,	Zr.	32.60
rum),	M.	48.00	Zirconium,		22.40
-Molybdenum,					
-Nickel,	Ni.	29.50			

A BINARY COMPOUND is a union of two elements, and in reading it the electro-negative is placed first and distinguished by the termination *ide*. Examples: chlorine and sodium form chloride of sodium; iodine forms iodides. In the case, however, of phosphorus, carbon, and sulphur, the termination *uret* is generally used. Example: iron and sulphur form sulphuret of iron. In writing the symbols the electro-positive element is placed first. An OXYD is a compound of O with an element. One equivalent of O is called the protoxyd; two, the deutoxyd or binoxyd; three of O to two of the other element, the sesquioxyd. Oxygen being negative to iron, when united they form an oxyd of iron, which is, therefore, written FeO; the deutoxyd of iron is FeO₂; the tritoxyd of iron is FeO₃; the sesquioxyd, Fe₂O₃.

Binary compounds are divided into three classes—ACIDS, BASES, and NEUTRALS.

An ACID is generally sour, and reddens blue litmus and green cabbage. It always unites with bases to form salts, which is the real test of an acid. Acids are of two kinds—Oxacids and Hydracids; the former contain O, the latter, H. The oxacids are named from the element with which the O unites, the termination indicating their strength—*ic* the stronger and *ous* the weaker. Example: sulphur forms two acids of different strength—sulphuric and sulphurous. If an acid has been found containing more O than the stronger, it takes the

prefix *per*; if one having less O, the prefix *hypo*. Examples :

Chloric acid.....	<chem>ClO5</chem>
Chlorous acid.....	<chem>ClO3</chem>
Perchloric acid.....	<chem>ClO7</chem>
Hypochlorous acid.....	<chem>ClO</chem>

The hydracids combine the names of both elements. Examples : hydrogen and chlorine form hydrochloric acid ; hydrogen and sulphur make hydrosulphuric acid.

A BASE is a substance that unites with an acid to form a salt. An alkali is a base that, in addition, has a soapy taste and feel, and changes red litmus to blue, and red cabbage to green. It turns the *ium* of its termination to *a*. Example : NaO is called the oxyd of sodium, and also soda. The alkalies neutralize the acids, and each restores the color removed by the other.

SALTS are ternary compounds, being composed of three elements. They are formed by the union of an acid and a base. In naming a salt the termination of the acid is changed—an *ic* acid forming an *ate* compound, and an *ous* acid an *ite* compound. The equivalent of O combined in the base is omitted. Examples : NaO.SO₃ is read, sulphate of soda ; FeO.SO₃, the sulphate of iron, and not the sulphate of the protoxyd of iron ; CaO.SO₂, sulphite of lime.

NEUTRALS have neither the properties of an acid

ence we can put this thought into the following algebraic form, under which should be solved the examples which follow, and many other similar ones, which the ingenuity of teacher and scholar will suggest. The book should be searched for symbols of compounds, and this part referred to throughout the study.

$$\text{Weight of one constituent} = \text{weight of given quantity} \left\{ \frac{\text{Equivalent of the constituent}}{\text{Equivalent of the compound}} \right\}$$

1. In making O from chlorate of potash (KO.CLO_5), how much can be obtained from two pounds of the salt?
2. In making H zinc is used. How much sulphate of zinc ($\text{ZnO.SO}_3 + 7\text{HO}$) will be formed from 2 lbs. of the metal?
3. How much SO_3 will be required to make 50 lbs. sulphate of iron ($\text{FeO.SO}_3 + 7\text{HO}$)?
4. The equivalent of the chloride of sodium (salt) is 58.5. In 10 lbs. there are $6\frac{8}{17}$ lbs. of sodium ; what is the equivalent of Cl?
5. In 20 grains of bromide of potassium there are $6\frac{8}{119}$ grains of potassium ; the equivalent of potassium being 39, what is the equivalent of the bromide of potassium?
6. In 14 lbs. of iron-rust (Fe_2O_3) how much O ?
7. In 20 lbs. of glass ($\text{NaO.SiO}_2 + \text{CaO.SiO}_2$) how many lbs. of sand (SiO_2) ?
8. In a 25 lb. sack of salt (NaCl) how many lbs. of the metal sodium ?

INORGANIC CHEMISTRY.

THE METALLOIDS.

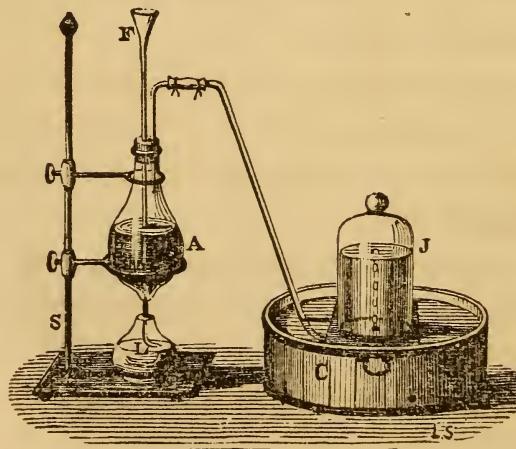
OXYGEN.

Symbol, O Equivalent, 8 Specific Gravity, 1.1.

THE name O means acid-former, and was given because it was supposed to be the essential principle of all acids; but hydrogen has since been found to possess the same property.

Source.—O is the most abundant of all the elements—comprising $\frac{1}{5}$ of the air, $\frac{8}{9}$ of the water, $\frac{3}{4}$ of all animal bodies, and $\frac{1}{2}$ of the crust of the earth.

Preparation.—The simplest method of making O for experimental purposes is to heat a mixture of chlorate of potash and black oxyd of manganese in a retort, and collect the gas over a pneumatic cistern, as in the accompanying illustration.



Making O.

The reaction—the chemical change—is as follows:



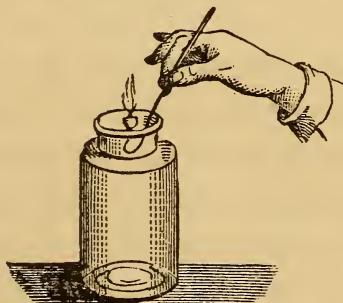
The Cl of the chloric acid unites with the K of the potash, forming KCl, chloride of potassium ; and the 5 atoms of O in the chloric acid and the atom of O in the potash, making 6 atoms of O, pass off as a gas.

A Curious Fact.—If the chlorate of potash were heated alone, when the requisite temperature was reached the gas would be liberated with very great rapidity. Sometimes, indeed, the change would be instantaneous—the solid of scarcely a cubic inch becoming in the twinkling of an eye a gas of 300 cubic inches, and, with an explosion like gunpowder, rending the retort into a thousand fragments. If, however, we mix with the chlorate of potash a little black oxyd of manganese, the gas will come off quietly and safely, a bubble at a time. At the conclusion of the process, the MnO₂ (the binoxyd, or black oxyd of manganese) will be found unchanged. The reason of this wonderful action is beyond our comprehension. It would seem that powdered glass or sand should produce the same result ; but, on trial, they fail. This influence of one body over another, by its mere presence, is called *catalysis*.

Properties.—O has no odor, color, or taste. It combines with every element except fluorine. From some of its compounds it can be set free by the stroke of a hammer, while from others it can be liberated only by the most powerful means. Its union with a substance is called *oxydation*, and the product an *oxyd*. It is a most powerful supporter of combustion.

Example: By blowing quickly upward upon a candle extinguish the flame, and leave a glowing wick. If this be plunged into a jar of pure O, it will burst into a brilliant blaze. The experiment may be repeated many times before the gas is exhausted. Carbonic acid is formed by the combustion.

Example: If a watch-spring be straightened in a spirit-lamp, and then tipped with melted sulphur, on igniting this and lowering it into a jar of O, the steel will crackle into a shower of fiery stars, and melted globules of oxyd of iron will fly in every direction.

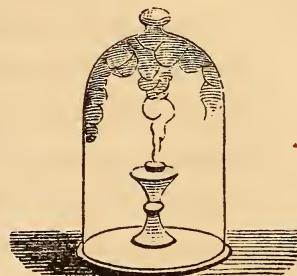


Candle in oxygen.



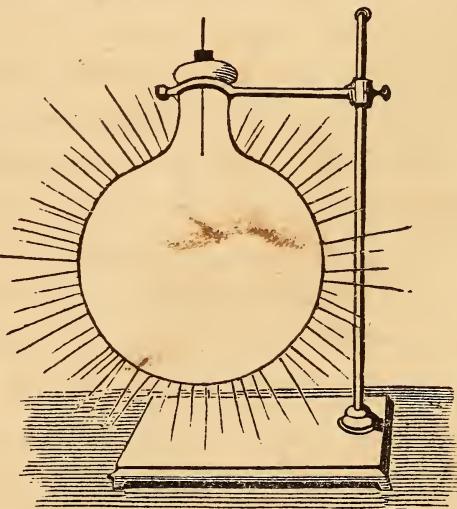
Watch-spring in oxygen.

Example: Ignite a bit of sulphur placed on a stand, and invert over it a jar of O: it will burn with a beautiful blue light, and the fumes of sulphurous acid (SO_2) will circle about the receiver in curious concentric rings.



Sulphur in oxygen.

Example: Place in the bottom of a "deflagrating spoon" a little fine, dry chalk; then wipe a bit of phosphorus very carefully and quickly between pieces of blotting-paper; lay this upon the chalk, and, holding the spoon over a large jar of O, ignite the phosphorus with a heated wire, and lower it steadily into the gas. The phosphorus will burst into a blinding flood of light, while dense fumes of phosphoric acid (PO_5) will roll down the sides of the jar.



Phosphorus in oxygen; "The phosphoric sun."

THE DESTRUCTIVE AGENT OF THE AIR.—O is the active principle of the atmosphere. It is destructive in all its effects. Comprising one-fifth of common air, it

is all around us, and, like a lurking lion, constantly on the watch for a chance to spring upon and devour something. We gather a basket of luscious peaches, and put them out of the way of the children ; but we cannot outreach the slyest pilferer of all—the O—and soon we will find the fruit covered with the prints of invisible teeth. Black spots appear, and we say they are decaying; it is only the O feasting upon them, and in a month it will devour them, skin and all. To prevent this, we put our fruit in a glass can, heat it to expel the O, seal it up tightly, and then it is safe from this chemical plunderer.

We open the damper of the stove, and the air rushes in. The O immediately attacks the fuel. Each pair of atoms catches up an atom of C between them, and flies off into the air as carbonic acid.—An animal dies. The O is on the alert; and, the instant his victim expires, and sometimes a little sooner, he is so anxious to commence, he begins to remove that which will soon be an offence to all sensitive nostrils.—We accidentally cut a finger, and soon find the unwelcome O tugging away at the quivering nerve beneath.—The keen throb with which an unsuspected hollow in a tooth is revealed to us, announces the entrance of the foe at an unguarded breach.—The HO in the cistern becomes foul and putrid. We uncover it. In rushes the O, picks up every atom of impurity, and drags it to the bottom. The thick sediment we find when we clean it the next summer, shows how faithfully it did its

work.*—We use our writing-fluid, and the words look pale and dejected. In a few hours we return, and even the letters stand out bold and clear. Noiselessly uniting with the iron of the ink, the skilful intruder has not disturbed the most delicate tracery in taking possession.—The blacksmith draws a red-hot iron from his forge. The O seizes the opportunity while the metal is glowing, and bites off great scales of the black oxyd of iron (Fe_3O_4) that fly in every direction.—We wipe our knives and forks, and carefully lay them away; but if we have left on them the least particle of moisture, as HO favors chemical change, the vigilant O will find it, and, if unmolested, will never stop until it has eaten the whole of the feast we have provided. But as heat is also productive of chemical action, and the Fe is now cold, it cannot combine as vigorously as at the blacksmith's forge; therefore, the compound is a lower one, the red oxyd of iron (Fe_2O_3) or common iron-rust, as we see it on stoves and other utensils.

O IN THE HUMAN SYSTEM.—We take the air into our lungs. Every three minutes all the blood in the system makes the tour of the body, and comes to

* "As the vessel sets sail from London, the captain fills the water-casks with water from the river Thames, foul with the sewage of the city, and containing 23 different species of animalculæ; yet, in a few days, the O contained in the air dissolved by the HO, will have cleansed it, and the HO will be found sweet and wholesome during the voyage."

the lungs. Now the blood is full of little iron disks, or gas-bags. These, when old, assume a tawny hue, like the decayed leaves of autumn, shrivel up and die, millions of them perishing at every breath we draw. But when young and vigorous, they take up the O and carry it to all parts of the body, depositing it wherever it is needed. Here the O revels in high life. It sweeps tingling through every artery and vein, distends each capillary tube, sends the quick flush to the cheek, snatches up its portion of the food that comes out of the stomach, gnaws away at the nerves and tissues, eats up every worn-out muscle and all waste matter, until at last it comes back through the veins black and thick with the products of its toil—the cinders of the fire within us.

COMBUSTION AND HEAT.—All processes of fermentation, of decay, of putrefaction, of fire, are called, by the chemist, by one name—combustion, or oxydation. They are simply produced by the union of O with the substance. They differ only in the time employed in the operation. If O unites rapidly, we call it fire; if slowly, decay. Yet the process and the products are the same. A stick of wood is burned in my stove, and another rots in the woods, and the chemical change is identical. In the combustion of an atom of O, a certain amount of heat is liberated. Hence, the house that decays in twenty years, gives out as much heat during that time as if it had been swept off in a fierce conflagration in as many minutes.

THE HUMAN FURNACE.—The body is a stove in which fuel is burned, and the chemical action is precisely like that in any other stove. This combustion liberates heat, and our bodies are kept warm by the constant fire within us. We thus see why we fortify ourselves against a cold day by an extra full meal. When there is plenty of fuel in our human furnaces, the O burns that; but if there be a deficiency, the destructive O must still unite with something, so it gnaws away at our flesh;—first the fat, and the man grows poor; then the muscles, and he grows weak; finally the brain, and he becomes crazed. He has simply burned up, as a candle burns out to darkness.

O PRODUCES MOTION.—The action of O in the movement of the muscles is very singular. In order to move a limb, the muscle must contract. So the O unites with a part of the muscle, destroys its structure, and so shortens it. Thus every movement of a limb, every wink of the eye, even, is performed by the disintegration of the muscle used. The truth of this is shown very clearly when we remember that, as soon as we begin to perform any unusual exercise, we commence breathing more rapidly,—showing that we need more O to unite with the muscles to perform the work. In very violent labor, as in running, we are compelled to open our mouths, and take in great swallows of oxygen. This roaring fire within elevates the temperature of the body, and we say “we are so warm that we pant.” Really it is

the reverse. The panting is the cause of our warmth. We need O, then, not only to keep us warm, but also to do all our work. Cut off its supply, and we grow cold, the heart struggles spasmodically for an instant, but the motive power is gone, and the wheels of life soon stand still.*

THE BURNING OF THE BODY BY O.—A man weighing 150 lb. has 64 lb. of muscle. This would be burned in about 80 days of ordinary labor. As the heart works day and night, it burns out in about a month. So that we have a literal “new heart” every thirty days. We thus dissolve, melt away in time, and only the shadow of our bodies can be called our own. They are like the flame of a lamp, which appears for a long time the same, since it is “ceaselessly fed as it ceaselessly melts away.” The rapidity of this change in our bodies is remarkable. Says Dr. Draper: “Let a man abstain from water and

* During sleep, the organs of the body are mostly at rest, except the heart. To produce this small muscular exertion very little O is required. As our respiration is, therefore, slight, our pulse sinks, the heat of our body falls, and we need much additional clothing to keep warm. Animals that hibernate show the same truth. The marmot, for instance, in summer is warm-blooded; in the winter its pulse sinks from 140 to 4, and it becomes cold-blooded. The bear goes to his cave in the fall, fat and plump; in the spring he comes out lean and lank. Cold-blooded animals have very inferior breathing apparatus. A snake, for example, has to swallow air by mouthfuls, as we do water. Others have no lungs at all, and breathe in a little air through their skin, enough to barely exist. Is it strange they are cold-blooded?

food an hour, and the balance will prove he has become lighter." At night a person is not quite so tall as in the morning. A French physiologist says his son lost an inch by a single night's dancing. This action of O, so destructive—wasting us away constantly from birth to death—is yet essential to our existence. Why is this? Here is the glorious paradox of life. *We live only as we die.* The moment we cease dying, we cease living. All our life is produced by the destruction of our bodies. Hence the necessity for food to supply the constant waste of our system, and for sleep to give nature time to repair the losses of the day. Thus, also, we see why we feel exhausted at night and refreshed in the morning.

O THE COMMON SCAVENGER.—God has no idlers in his world. Each atom has its use. There is not an extra particle in the entire universe. So the O collects every waste substance, picks up every straggler, and returns it to the common stock, for use in nature's laboratory. In performing this task, its mission is most important and necessary. It sweetens water, it keeps the avenues of the body open and unclogged, it preserves the air wholesome. Oxygen is, in a word, the universal scavenger of nature. No matter can hide away from its keen eye. Every dark cellar of the city, every recess of the body, every nook and cranny of creation, finds it waiting; and the instant an atom is exposed, the oxygen pounces upon it. A leaf falls, and the O forthwith commences

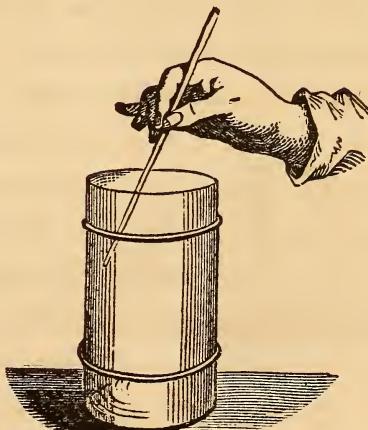
its destruction. A tiny twig, far out at the end of a limb, dies, and the O immediately begins its removal. A pile of decaying vegetables, a heap of rubbish, the dead body of an animal, a fallen tree, even the houses we erect for our shelter the very instant they are built, all are gnawed upon by what we call the "insatiate tooth of time." It is only the constant corrosion of this destructive agent—oxygen.

ACTION OF PURE O IN THE BODY.—The action of undiluted oxygen on the animal system is exhilarating in the highest degree. A rabbit immersed in a receiver of this gas soon feels its effect, bounds off into a delirium of excitement, and in a few hours by this quick combustion burns out its little lamp of life. Were we to breathe pure O, the fiery gas would leap through our arteries like a hungry tiger, the heart would throb against the ribs with the stroke of a trip-hammer, the veins would dilate with the increasing tide of blood, the eyes would glisten and glare: the gestures and motions would be at first quick, lively, vivacious, then hurried and restless, then eager and startling, at last furious and raving; and if the inhalation of the gas still continued, stark insanity would end the drama of life.

RESULTS IF THE AIR WERE PURE O.—Were the air pure O, the fire element would run riot everywhere. Our lamps would burn with the oil they contain. Our stoves would blaze with a shower of sparks. A fire once kindled would spread with ungovernable velocity. In a conflagration, not only would the

timber of a house burn, but the nails, the foundation, and even the very water poured upon it to extinguish the flames.

OZONE.—Ozone is an *allotropic* form of O—*i. e.*, a form in which the element itself is so changed as to have new properties. It is always perceived during the working of an electric machine, and is then called “the electric smell.” It has also been detected near objects just struck by lightning. The electricity of the atmosphere is supposed to have something to do with its formation. Its test is a paper wet with a mixture of starch and iodide of potassium (KI). The ozone sets free the iodine, and that unites with the starch, forming the blue iodide of starch. Its identity with O is easily shown. Example: Pour a little ether into a jar of common air, and stir in its vapor a heated glass rod. The O will be immediately changed into its allotropic form—ozone, which can be recognized by its pungent odor and the test just named. If the ozone be afterward passed



Making ozone.

through a red-hot tube, it will come out the original O. Ozone is much more corrosive even than oxygen. It bleaches powerfully, and is a rapid disinfectant. A piece of tainted meat plunged into a jar of ozone

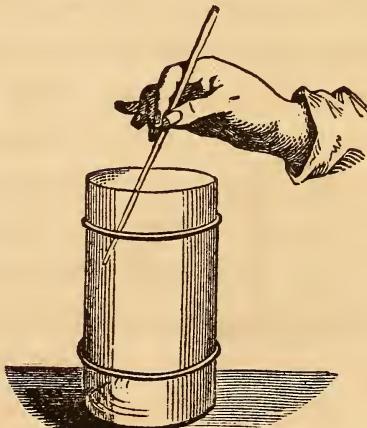
its destruction. A tiny twig, far out at the end of a limb, dies, and the O immediately begins its removal. A pile of decaying vegetables, a heap of rubbish, the dead body of an animal, a fallen tree, even the houses we erect for our shelter the very instant they are built, all are gnawed upon by what we call the "insatiate tooth of time." It is only the constant corrosion of this destructive agent—oxygen.

ACTION OF PURE O IN THE BODY.—The action of undiluted oxygen on the animal system is exhilarating in the highest degree. A rabbit immersed in a receiver of this gas soon feels its effect, bounds off into a delirium of excitement, and in a few hours by this quick combustion burns out its little lamp of life. Were we to breathe pure O, the fiery gas would leap through our arteries like a hungry tiger, the heart would throb against the ribs with the stroke of a trip-hammer, the veins would dilate with the increasing tide of blood, the eyes would glisten and glare: the gestures and motions would be at first quick, lively, vivacious, then hurried and restless, then eager and startling, at last furious and raving; and if the inhalation of the gas still continued, stark insanity would end the drama of life.

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Making ozone.

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is instantly purified. Its abundance in the air produces influenzas, diseases of the lungs, etc.; its absence, fevers, agues, etc.

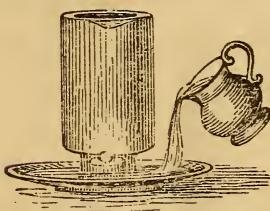
NITROGEN.

Symbol, N Equivalent, 14 Specific Gravity, 0.97.

This gas is called nitrogen because it exists in nitre.

Sources.—Nitrogen is found largely in ammonia and nitric acid. It forms $\frac{1}{5}$ of dried flesh, $\frac{4}{5}$ of the atmosphere, and exists abundantly in mushrooms, mustard, cabbage, horse-raddish, turnips, etc. The peculiar odor of burnt hair or woollen is given by the N compounds they contain.

Preparation.—It is prepared by putting in the centre of a deep dish of water a little stand several inches in height, on which a bit of phosphorus may

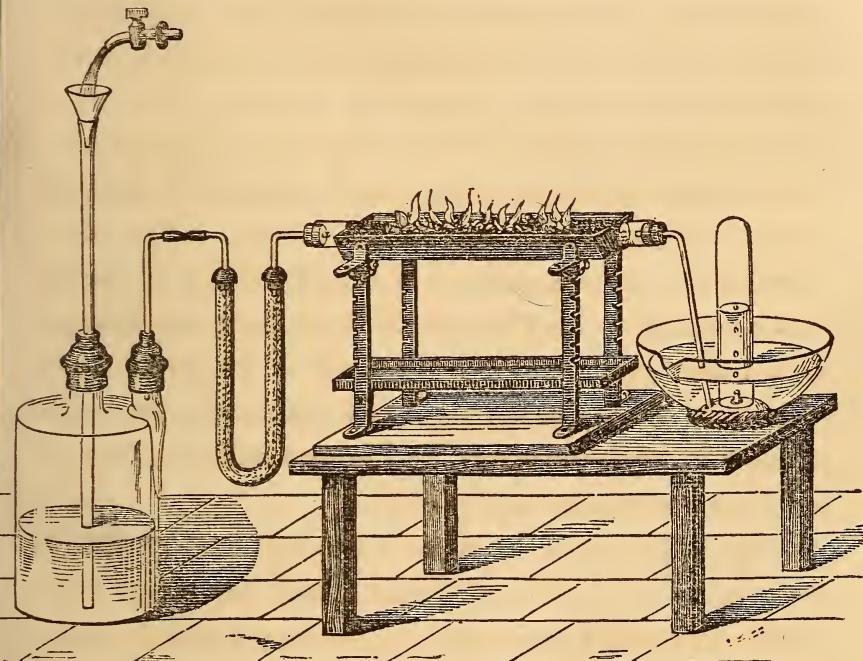


Making nitrogen.

be laid and ignited. As the fumes of phosphoric acid ascend, invert a receiver over the stand. The phosphorus will consume all of the O of the air contained in the jar, leaving the N. As the water in the plate rises, add more as needed. It should occupy $\frac{1}{5}$ of the receiver. The jar will at first be filled with white fumes (PO_5), but the water in a few minutes will absorb these.

Another Method.—Nitrogen may also be prepared in large quantities in the manner shown in the

illustration. At the left is a stream of water which falls through a funnel tube into a "Woulfe's bottle." The U-shaped tube is filled with bits of chloride of



Making nitrogen.

calcium to absorb the moisture; and a second tube should be added, filled with pumice-stone, moistened with caustic potash, to deprive the air of its carbonic acid. The long tube is filled with copper turnings, heated by the furnace-fire. The air from the bottle is driven by the falling water up through the U tubes, where it loses its water and carbonic acid; thence among the red-hot copper-turnings, which unite with its O: after which the N, deprived of all its companions, bubbles up through the water into the receiver.

Properties.—All descriptions of nitrogen are of a negative character. It neither burns nor permits anything else to burn. It neither supports life nor destroys it. Yet a candle will not burn in it, and a person cannot breathe it alone and live, simply because it shuts off the life-giving oxygen. So will a person drown in HO, not that the water poisons him, but because it fills his lungs, and shuts out the air: N does not unite with any of the metals. *The instability of all its compounds is its striking peculiarity.* For instance, it may be induced to join its fortune with iodine, but so gingerly, that if we even tread heavily in the room where it is kept, it will leave its partner in high dudgeon, and bound off into the air with a tremendous explosion.

Uses.—RELATION OF N TO ORGANIC SUBSTANCES.— Four-fifths of each breath that enters our lungs is N; yet it comes out as it went in, leaving the remaining fifth, O, to perform its wonderful mission within our bodies. One-fifth of our flesh is N, yet none of it comes from the air we breathe. We obtain all our supply from the lean meat and vegetables we eat. Plants breathe the air through the leaves—their lungs; yet they do not appropriate any of the N obtained in this way, but rely upon the ammonia and nitric acid their roots absorb from the soil. N enters the stove with the O: the latter unites with the fuel; but the former, disdaining any such work, passes on out of the chimney. Even from a blast-furnace, where iron instantly melts like wax, the N

comes forth without the smell of fire upon it. So unsocial is it, that it will not affiliate directly with any organic substance. We must all, animals and plants, depend upon finding it bound hand and foot in some chemical compound, and so appropriate it to our use. But even then we hold it very loosely indeed. The tendency of flesh to decompose is mainly owing to the instability of the N in its composition.

DIFFERENCE BETWEEN N AND O.*—We see now how different N is from O. The one is the conservative element, the other the radical. But notice the nice planning shown in the adaptation of the two to our wants. O, alone, is too active, and must be restrained. Were the air pure O, our life would be excited to a pitch of which we can scarcely dream, and would sweep through its feverish, burning course in a few days. Four parts of the negative N just restrain the O within governable limits, adapt it to our needs, and make it our useful servant.

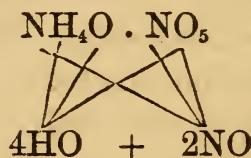
O AND N COMBINED.—Separately, either element of the atmosphere would kill us. The fiery O and the inert N combined give us the golden mean. The O now quietly burns the fuel in our stoves and keeps us warm ; licks up the oil in our lamps and gives us light ; corrodes our bodies and gives us strength ;

* The difference between these two gases can be best illustrated by having a jar of each, and rapidly passing a lighted candle from one to the other : you will extinguish the light in the first, and relight the coal in the second. By dexterous management this may be repeated a dozen times.

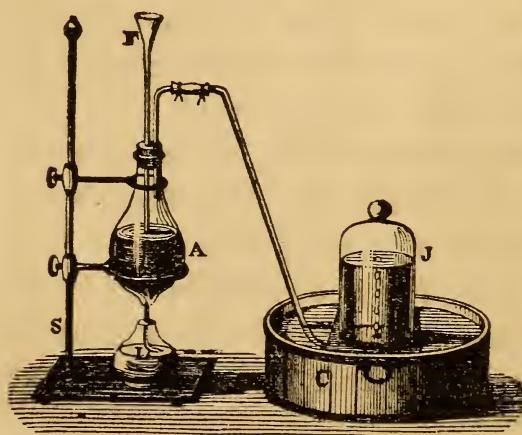
cleanses the air and keeps it fresh and invigorating; sweetens foul water and makes it wholesome; works all around and within us a constant miracle, yet with such delicacy and quietness that we never perceive or think of it until we see it by the eye of science.

NITROUS OXYD, NO—LAUGHING GAS.

Preparation.—This gas is made by heating nitrate of ammonia. The reaction is as follows:



The atom of N and two atoms of O from the nitric acid unite with the atom of N from the ammonia, forming 2NO. The four atoms of H in the ammonia unite with three atoms of O in the nitric acid and the one atom of O in the ammonia, forming 4 atoms of HO.



Properties.—It supports combustion almost equally with O, and, like it, is colorless and odorless. It

is soluble in HO, and liquefies at 45° F., with a pressure of 50 atmospheres. It has a sweet taste, and is chiefly noted for its anæsthetic properties.

ACTION ON HUMAN SYSTEM.—When breathed, it produces a species of intoxication. The feeling is generally one of perfect bliss and contentment. A feverish glow overspreads the body, and a thousand delightful visions pass before the mind. The cares and troubles of life

“ Fold their tents like the Arabs,
And as quiet steal away.”

A wild, delicious, dreamy joy spreads through the system, and annihilates all idea of time and space. The first inhalation of the gas sometimes causes bursts of laughter, hysterical weeping, or loud, unmeaning talking. Then succeeds a glow of warmth, first felt in the extremities, followed by a prickly, benumbed sensation, a confusion of ideas, noises in the ears (frequently compared to the vibration of an engine from one side of the head to the other), and occasionally flashes of light before the eyes. With this stage all sensation and voluntary motion cease. Without any ability to act, one is yet frequently entirely conscious of all that takes place. During this, the anæsthetic state, perfectly painless operations can be performed. Often the patient will awake, remembering all that has occurred, yet having felt no pain.

For scientific purposes, or for amusement, the

inhalation is stopped before the anæsthetic stage is reached. One can administer the gas to himself with perfect safety after a few trials. Before inhaling, he may decide what he will do while under its influence, laugh, sing, declaim, etc.; and keeping this idea and no other upon his mind while breathing, he will find himself irresistibly impelled to perform it. If he has no especial thought in his mind, he is left to the inspiration of the moment, and may do any absurd thing the occasion may suggest, from holding his nose and bowing continually to the audience, to clearing the stage of its occupants. The gas does not "bring out the natural disposition of the person," as some have believed. As soon as its influence passes off, the hand seeks the forehead with returning consciousness, the eye resumes its natural expression, the pulse sinks to a slightly quickened beat, and the dream is over.

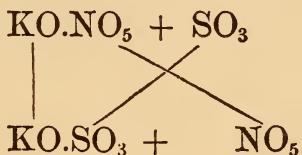
EXPLANATION.—The exciting effect of this gas is due to the excessive supply of O it furnishes the system. When the carbonic acid gas, formed by this unusual combustion, accumulates in the veins, by its narcotic influence it produces a temporary insensibility.

Caution.—The utmost care should be used in preparing NO. It should stand over HO at least 12 hours before inhalation, although agitation with several gallons of HO in the gas-bag is a safe precaution. No one should ever breathe it who is not in good health at the time, who is troubled with a rush

of blood to the head, any lung or heart disease, or is of a plethoric habit. With proper caution, no accident need ever occur.

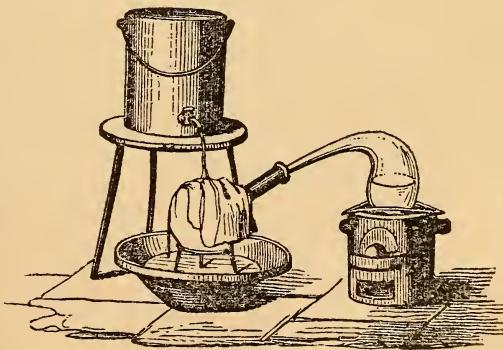
NITRIC ACID (AQUAFORTIS), NO_5 . HNO_3

This acid is found in nature, in combination with soda or potash, and is obtained in a separate state by the addition of a stronger acid, which drives off the weaker and usurps its place. Thus, taking KO.NO_5 , and adding SO_3 , the following chemical change ensues, while the acid is collected in a receiver, cooled by dropping water:



It is formed in small quantities in the atmosphere by the union of its elements during the passage of electricity, as in a thunder-storm, and being washed to the earth by rain, is absorbed by the roots of plants.

Properties.—It is an intensely corrosive, poisonous liquid. When pure, it is colorless, but as sold,



Making NO_5

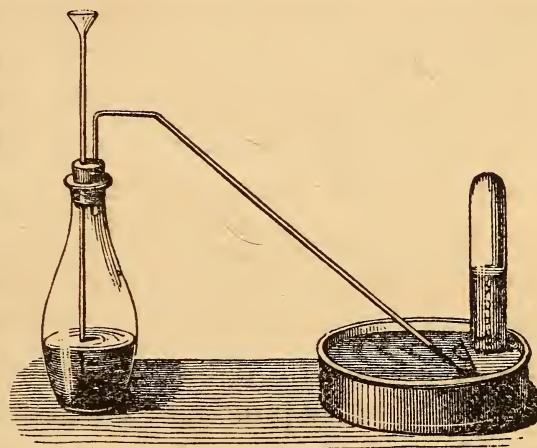
has commonly a golden color, from the presence of the red fumes of nitrous acid, produced by the decomposing action of the light. It has been obtained in the form of brilliant transparent crystals, but is always found dissolved in HO, sometimes of twice its own weight, never less than $\frac{1}{4}$. In strength, it is next to SO₃. It stains the skin, wood, etc., a bright yellow.

Uses.—It gives up its O very readily, and thus corrodes any substance with which O will combine. It is employed in dyeing woollen yellow, and in surgery for cauterizing the flesh. It dissolves most of the metals, and in combination with HCl, forms aqua-regia, the only solvent of gold. It etches the lines in copperplate engraving, and the beautiful designs on the blades of razors, swords, and other steel utensils. The process is very simple. The surface is covered with a varnish impervious to NO₅; the desired figure is then sketched in the varnish with a needle. The NO₅ being poured on, oxydizes the metal in the delicate lines thus laid bare.

ACTION ON THE METALS.—If a bit of Sn be placed in NO₅, the acid will immediately give up to it three atoms of its O, making the metal an oxyd (SnO₂), and reducing itself by the operation to NO₂ (nitric oxyd); this passes off into the air as a gas, and eagerly seizing upon two atoms of O in the air, becomes NO₄ (nitrous acid), which we readily recognize by its brilliant, red-colored fumes. If, instead of the Sn, Cu be used, the action is somewhat different. A

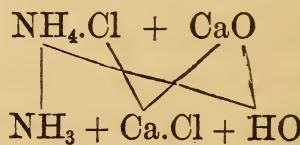
portion of the acid unites with the Cu, forming an oxyd (CuO); but another portion instantly combines with CuO , making $\text{CuO} \cdot \text{NO}_5$. This we detect by the deep blue color it gives to the liquid. If we now evaporate the HO from this solution, we will obtain beautiful blue crystals of the salt.

The experiment may be performed with the apparatus shown in the cut. The nitric oxyd, NO_2 , caught in the receiver, will be found colorless, while, on admitting a bubble of air, blood-red fumes of NO_4 will fill the jar.

Making NO_2

AMMONIA, NH_3 .—This gas is also called hartshorn, because in England it was formerly made from the horns of the hart. It received the name *ammonia*, by which it is now more generally known, from the temple of Jupiter Ammon, near which sal-ammoniac, one of its compounds, was once manufactured. The *aqua-ammonia* of the shops, which is merely a strong solution of the gas in HO, is obtained from the incidental products of the gas-works in large quantities. Water absorbs from 400 to 500 times its own bulk of ammonia. When undiluted, it will produce

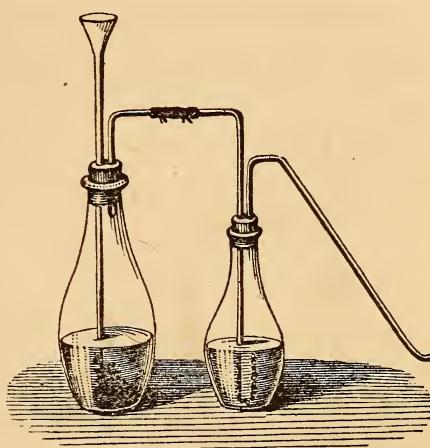
a blister, and should, therefore, be very much weakened before being tasted or touched. It is a strong alkali, and turns the vegetable blues to greens; but owing to its volatility this change of color is only temporary. It is, therefore, sometimes termed "the volatile alkali." Its test is hydrochloric acid, HCl. Example: If we bring a stopple wet with HCl near this gas, it will instantly reveal itself by a dense cloud of white fumes, the chloride of ammonium, sal-ammoniac, which floats in the air like smoke. The antidote of ammonia is vinegar. Its pungent odor can always be detected near decaying vegetable or animal matter. Smelling-bottles are filled with a mixture of finely powdered sal-ammoniac and lime. By this method, ammonia is also made in the arts. The process is hastened by applying heat. The reaction is as follows:



One atom of H of the sal-ammoniac unites with the O of the lime, forming HO. The calcium of the lime combines with the chlorine, producing chloride of calcium, and the NH₃ is set free as a gas which may be absorbed by water, as in the adjoining illustration, thus forming aqua-ammonia.

Nascent state.—If N and H, the elements of NH₃, be mixed in a receiver, they will not unite chem-

ically, owing to the negative character of N, of which we have before spoken. When, however, any substance is decomposed which contains both of them, as bituminous coal, flesh, etc., at the very instant of their separation from their compounds, in the first feeling of their loneliness, as it were, they will combine and form NH_3 . This moment, when elements are thus in the act of leaving their compounds, is called their "nascent state."

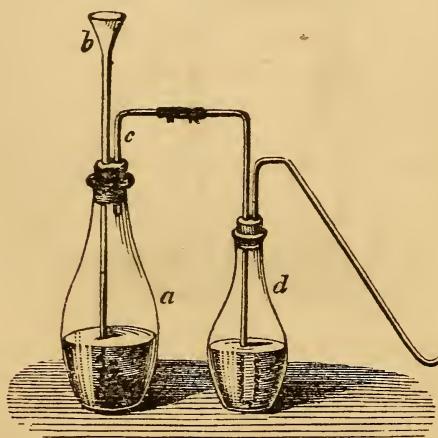
Making NH_3

CHLORIDE OF AMMONIUM, MURIATE OF AMMONIA, SAL-AMMONIAC, NH_4Cl .—In the ammoniacal liquors just named, and in the distillation of horns, hoofs, horse-flesh, woollen rags, etc., carbonate of ammonia is formed. By mixing this with HCl , that acid drives off the CO_2 , and takes its place, thus producing chloride of ammonium. On evaporating the solution, tough, fibrous crystals are obtained. They reveal no trace of the pungent ammonia, yet it can be easily set free, as we have already seen. Sal-ammoniac is soluble in HO ; is used in medicine, and also in soldering, the HCl it contains dissolving the coating of the oxyd of the metal, and preserving the surfaces clear for the action of the solder.

HYDROGEN.

Symbol, H Equivalent, 1 Specific Gravity, .069.

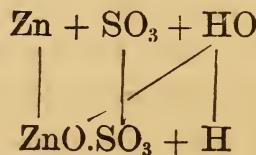
Hydrogen means literally a generator of water.



Making hydrogen.

Preparation.—It is always obtained by the decomposition of HO, of which it forms $\frac{1}{9}$ part by weight. If we place in an evolution flask (a common junk bottle will answer) bits of zinc, and then pour through the funnel tube sulphuric acid (SO_3) and HO, the

gas will be evolved abundantly. The reaction is as follows:



The zinc decomposes the HO uniting with the O, forming ZnO, and setting free the H, which passes off as a gas. But the ZnO would soon form a coating over the metal, and protect it from the HO; this the SO_3 prevents by combining with the ZnO, forming $\text{ZnO} \cdot \text{SO}_3$ (white vitriol), and so keeping the surface of the zinc bright and the action constant. The

black specks which appear floating about in the solution are charcoal from the Zn. The white vitriol which is formed soon gives the mixture a milky-white appearance. By evaporating the HO, the crystals of this salt can be obtained.

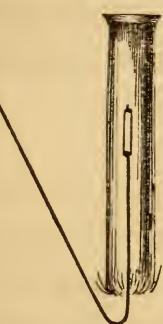
Properties.—H prepared in this manner has a disagreeable odor, from various impurities in the materials used. When pure, like O, it is colorless, transparent, and odorless. Its atoms are the smallest of any known element; and in attempts made to liquefy the gas, it leaked through the pores of the thick iron cylinders in which it was compressed. It is the lightest of all bodies, being only $\frac{1}{4}$ as heavy as common air. It is not poisonous, although, like N, it will destroy life or combustion by shutting out the life-sustainer, O. When inhaled, it gives the voice a ludicrously shrill tone. It can be breathed for a few moments with impunity, if it be first passed through lime-water to purify it. Owing to its lightness, it passes out of the lungs again directly. Its levity suggested its use for filling balloons, and it has been used for that purpose;* but coal gas, which contains much H, and is cheaper, is now preferred.

COMBUSTION OF H.—A lighted candle, plunged into

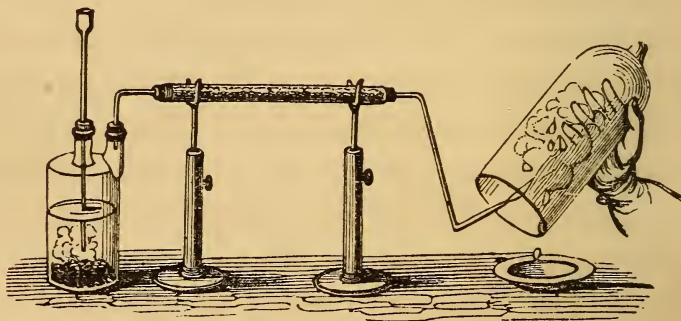
* We read, in accounts of fêtes at Paris, of balloons ingeniously made to represent various animals, so that aerial hunts are devised. The animals, however, persistently insist upon ascending with their legs up—a circumstance productive of great mirth in the crowd of spectators.

an inverted jar of this gas, is extinguished, while the gas itself takes fire, and burns with a pale blue flame.

One atom of the O of the air unites with an atom of the H, and the product of the combustion is HO, which may be condensed on a cold tumbler, held over a jet of the burning gas, as in the accompanying figure.



Mixed Gases.—A mixture of two parts, by measure, of H, with one part of O, or five parts of common air, will explode with a deafening report. The bulky gases being instantly condensed into a mere drop of HO, only $\frac{1}{1700}$ as large, a vacuum is produced, and the



Burning H.

particles of air rushing in to fill the empty space, by their collision against each other, produce the stunning sound. While the detonation is so great, the force is slight, as may be shown by exploding the bubbles in the hand. The two gases may be mingled in the right proportion and kept for years, and there

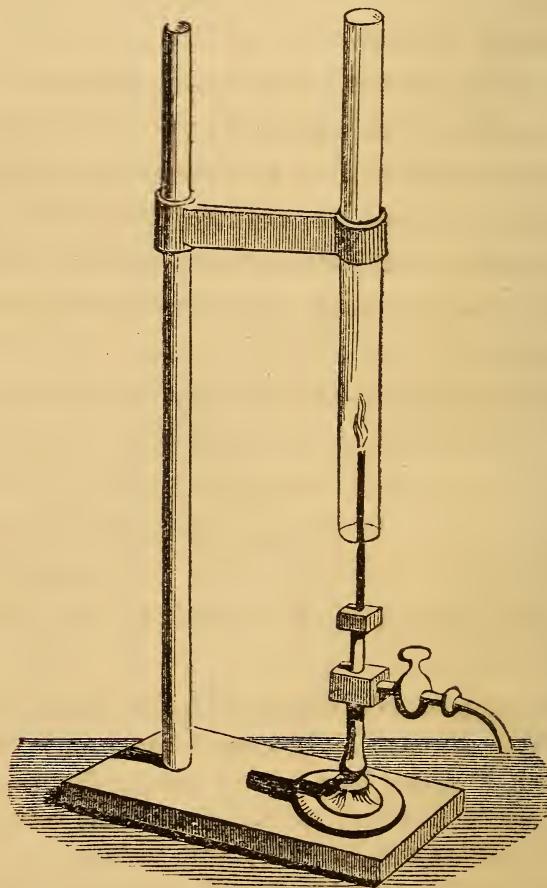
will be no change. The atoms lie against each other quietly, "cheek-by-jowl," without any manifestation of their chemical affinity, when suddenly, at the contact of the merest spark of fire, they rush together with a crash of thunder, and uniting, form the bland, passive liquid—water.

ACTION OF PLATINUM SPONGE.—A piece of platinum sponge placed in a jet of H will ignite it. This curious effect seems to be produced in the following way: The atoms of H and the O of the air are brought so closely together in its minute pores that they unite, and the heat thus produced sets fire to the gas.

HYDROGEN TONES.*—A singular illustration of the laws of sound can be given by simply holding a long glass tube, by means of a suitable clamp, over a minute jet of burning H. At first no effect will be produced; but as we slowly introduce the jet further and further into the tube, a faint sound is heard, apparently

* Another illustration of singing hydrogen may be represented in the following manner: Make a jar of heavy tin, in the form of a double cone, 12 inches long and 4 inches in diameter. At one apex fit a nozzle and cork, at the other, make several minute openings. Covering these openings with sealing-wax, and drawing the cork, fill the jar with H, and replace the cork. When ready for use, hold the jar in a vertical position, remove the wax from at least one orifice, ignite the H at that point, and draw the cork. Still hold the jar quietly, and in a minute or two the tiny jet of H will begin to sing like a swarm of mosquitoes, buzzing and humming in the most aggravating way until, most unexpectedly, the scientific music ends in a loud explosion.

in the far-off distance. This gradually approaches, and finally bursts into a shrill, continuous, musical note—the key-note of the heated column of air within the tube. The cause of this is thought to be



Hydrogen Tones.

that the flame is momentarily extinguished and re-lit with a slight explosion, and these, rapidly repeated, produce the musical note. Indeed, these explosions may be made so slow that the quivering

of the flame can be seen, and the sound cease to be continuous as before. Let us now place the tube at a point where no clapping of hands or unusual sound will start it into song. Let various tones be produced from a violin, and we will find the flame responding only to that tone which is the key-note of the tube, or its octave. The violin player will have perfect control of this scientific music, and can start, stop, or throw it into violent convulsions, even across a large hall. Tubes of different sizes and lengths will give tones of diverse character and pitch. The waves of sound from the instrument augmenting or interfering with those in the tube will probably account for these phenomena.

WATER.

Symbol, HO....Equivalent, 9....Freezes at 32°F....Boils at 212°F.

The composition of HO is proved by analysis and synthesis—*i. e.*, by separating the compound into its elements, and by combining the elements to produce the compound. We can analyze it in the manner already shown in preparing H, or by passing through it a galvanic current, when the O will appear in bubbles of gas at the positive pole, and the H in a similar way at the negative. In the synthetic method, we mix the two gases, and unite them as we have before by an electric spark. The blacksmith decomposes water when he sprinkles it on the hot coals in his forge. The H burns with a blue flame, while the

O increases the combustion. Thus, in a fire, if the engines throw on too little water, it will be decomposed, and so add to the fury of the flame. To "set the North River on fire" is only a poetical exaggeration.

The quantity of electricity required to decompose a single grain of water is estimated to be equal to a powerful flash of lightning. The enormous force necessary to tear these two elements from each other shows the wonderful strength of chemical attraction. We thus see, that in a tiny drop of dew there slumbers the latent power of a thunderbolt.

WATER IN THE ANIMAL WORLD.—The abundance of water very forcibly attracts the attention. It constitutes four-fifths of our flesh and blood. Man has been facetiously described as 12 lbs. of solid matter wet up in six pails of water. All plumpness of flesh, all fairness of the cheek, are given by the juices of the system. A few ounces of water causes the physical difference between the round, rosy face of sixteen, and the wrinkled, withered features of three-score and ten. Our tears, poetical as they may seem to us sometimes, are only water and a pinch of salt. To supply the wants of the system each man needs about $\frac{3}{4}$ of a ton annually. When we pass to lower orders of animals, we find this liquid still more abundant. Sunfishes are little more than organized water. Professor Agassiz analyzed one found off the coast of Massachusetts, which weighed 30 lbs., and obtained only $\frac{1}{2}$ an ounce of dried flesh. Indeed,

naturalists state that an entire order of animals (aca-lephs), belonging to which are the jelly-fish, medusa, etc., is composed of only ten parts in a thousand of solid matter.

WATER IN THE VEGETABLE WORLD.—In the vegetable world we find it abundant. Wood is composed of 12 parts charcoal and 10 parts water, with a little mineral matter comprising the ashes. Bread is half water; and of the potatoes and turnips cooked for our dinner, it comprises 75 parts of one and 90 of the other. The following table shows the proportion in common vegetables, fruits, and meats :

Mutton . . . . .	.71	Trout . . . . .	.81	Cabbage . . . . .	.92
Beef . . . . .	.74	Apples . . . . .	.80	Cucumbers . . . . .	.97
Veal . . . . .	.75	Carrots . . . . .	.83	Watermelons . . . . .	.98
Pork . . . . .	.76	Beets . . . . .	.88		

In all these instances water is essential to the structure and constitution of the various substances. Remove it, and they are decomposed into entirely new compounds.

WATER IN THE MINERAL WORLD.—Here we find a class of bodies in which the water is chemically combined in definite proportions. Such are called *hydrates*. In the image which the Italian pedler carries through our streets for sale, there is 1 lb. of HO to every 4 lbs. of plaster of Paris. One-third of the weight of the soil of our farms is this same liquid. Each pound of strong NO₃ contains 2½ oz. of water, which, if removed, would destroy the acid

itself. If we expel the water from oil of vitriol, it will lose its acid properties, and we can handle it with impunity. In bodies which are capable of crystallizing, it seems only to determine the form and general appearance, and is called "the water of crystallization." If we evaporate this from blue vitriol, it will lose its color and become white like flour. A few drops of HO will restore the blue. If we expel it from alum, it will puff up, and the transparent crystals will dry into an incoherent mass. Water of crystallization gives all the transparency to the opal, which else would be only common flint-stone.

WATER AS A SOLVENT.—Water, having no taste, color, or odor itself, is perfectly adapted to become the universal solvent, receiving instantly the characteristics of any substance placed in it. It becomes at pleasure sweet, sour, salt, bitter, nauseous, and even poisonous. Had water any taste, the whole science of cookery would be changed, since each substance would partake of the one universal watery flavor.

PURE WATER.—Rain-water, caught after the air is thoroughly cleansed by previous showers, and at a distance from the smoke of cities, is the purest natural water known. This is tasteless, yet its insipidity makes it seem to us very ill-flavored indeed. We have become so accustomed to the taste of the impurities in hard water, that they have become to us tests of its sweetness and pleasantness.

HARD WATER.—As water filters down through the

soil into our wells, it dissolves the various mineral matters characteristic of the locality. The most common of these are lime, salt, and magnesia. The former produces a *fur* or coating on the bottom of our teakettles, if we live in a limestone region. When we put soap in such water, it curdles—*i. e.*, it unites with the lime, forming a new or lime soap, which is insoluble in HO.

SEA-WATER.—Common salt is the most abundant mineral in the ocean. Yet it contains traces of every substance soluble in water, which has been washed into the sea from the surface of the continents during all the ages of the past. Its saline constituents are now in the proportion of about a $\frac{1}{2}$ oz. to a lb., which amount must be slowly increasing, as the water which evaporates from the surface is comparatively pure, containing only a mere trace of a few substances, which give to the sea-breeze its peculiar bracing, tonic influence. In this way, the water of the Salt Lake has become the strongest of brine, nearly one-third of its whole weight consisting of saline matter. This condition would soon disappear if an outlet could be provided.

WATER ATMOSPHERE.—As the world of waters is inhabited, it has its atmosphere also.* Inasmuch as the HO dilutes the O in part, it does not need so

* Fish breathe O through the fine silky filaments of their gills. When a fish is drawn out of HO, these dry up, and he is unable to breathe, although he is in a more plentiful atmosphere than he is accustomed to enjoy.

much N as the common air. It is accordingly composed of $\frac{1}{3}$ O instead of $\frac{1}{5}$. The air so rich in O thus absorbed by the water gives it its life and briskness. If it be expelled by boiling, the water tastes flat and insipid.

PARADOXES OF HO.—“Cold contracts,” is the law of physics; but as HO cools, it obeys this principle only as far as 39° F. Then it slowly expands, cooling down to 32°, its freezing point, when its crystals suddenly dart out at angles to each other, and thus, increasing its size $\frac{1}{10}$, it congeals to ice. By this wise exception, ice is lighter than HO, and so swims on top; otherwise our rivers would freeze solid, killing the fish and aquatic plants. The longest summer could not melt such an immense mass of ice. But now the blanket that nature kindly weaves over the rivers and ponds keeps their finny inhabitants warm and comfortable till spring; then she floats it south to melt under a hotter sun. Water is full of contradictory terms. We have hard water and soft water, fresh water and salt water. Water seems the most yielding of substances, yet the swimmer who falls on his face instead of striking head foremost understands the mistake, and we could drive a nail into a *solid* cube of steel easier than into a *hollow* one perfectly filled with HO. H is the lightest substance known, and O is an invisible gas; yet they unite and form a liquid whose weight we have often experienced, and a solid which makes a pavement as hard and unyielding as granite. H burns readily and explodes

most fearfully, O supports combustion brilliantly—yet the two combined are used to extinguish fires.

USES OF WATER.—The uses of water are as poetical as they are practical. Its properties, already discussed in Natural Philosophy, of specific heat, of expanding as it solidifies, together with that we have just named of dissolving such a wide range of gases and solids, fit it for a wonderful variety of operations in nature. Its office is not merely to moisten our lips on a hot day, to make a cup of strong tea, to lay the dust in the street, and to sprinkle our gardens. It has grander and more profound uses than any of these. *Water is the common carrier of creation.* It dissolves the elements of the soil, and climbing as sap up through the delicate capillary pump of the plant, furnishes the leaf with the materials of its growth. It flows through the body as blood, floating to every part of the system the life-sustaining O, and the food necessary for repairs and for building up the various parts of the “house we live in.” It comes in the clouds as rain, bringing to us the heat of the tropics, and tempering our northern climate, while in spring it floats the ice of our rivers and lakes away to warmer seas to be melted. It washes down the mountain side, levelling its lofty summit and bearing mineral matter to fertilize the valley beneath. It propels water-wheels working forges and mills, and thus becomes the grand motive-power of the arts and manufactures. It flows to the sea, bearing on its bosom ships conducting the com-

merce of the world. It passes through the arid sands, and the desert forthwith buds and blossoms as the rose. It limits the bounds of fertility, decides the founding of cities, and directs the flow of trade and wealth.

CARBON.

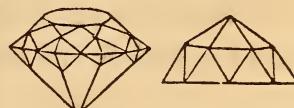
Symbol, C Equivalent, 8.

Carbon is one of the most abundant substances in nature, forming nearly one-half of the entire vegetable kingdom, and being a prominent constituent of limestone, corals, marble, magnesian rocks, etc. We find it in three distinct forms or allotropic conditions—viz., the *diamond*, *graphite*, and *amorphous carbon*. This last term means without form or crystals, and includes gas-carbon, charcoal, lamp-black, coal, coke, peat, soot, bone-black and ivory-black. In each of these various substances C possesses different properties; yet any impurities it may contain seem entirely incidental, and not at all necessary to its new state.

PROOF OF THIS ALLOTROPIC STATE.—Chemists have changed most of these substances into other allotropic forms. Thus, common charcoal has been turned into graphite, mineral coal into gas-carbon, the diamond into coke. All of them, when heated in the open air, unite with the same quantity of O, forming precisely the same compound—carbonic acid gas—from which the carbon can be obtained again in the form of charcoal.

THE DIAMOND is *pure carbon* crystallized. It is the hardest of all known substances, scratches all other minerals and gems, and can be cut only by its own dust. It is infusible, but will burn at a high temperature. It is found in various parts of the world—North Carolina, Georgia, Borneo, and Brazil. The ancient mines of Golconda, in Hindostan, are not now worked. In 1858, Brazil furnished 120,000 carats.* Diamonds are supposed to be of vegetable origin, and to have exuded, at some past time, as gum does now from cherry-trees, and then slowly crystallized. When found, they look like round pebbles, and are covered with a thin crust, which being broken reveals the brilliant gem within. They are of various colors, though often colorless and perfectly transparent. The latter are most highly esteemed, and, from their resemblance to a drop of clear spring-water, are called diamonds of the “first water.”

THE DIAMOND IS GROUNDED by means of its own powder. Being fitted to the end of a stick or handle, it is pressed down firmly against the face of a rapidly revolving wheel, covered with diamond-dust and oil. This, by its friction, removes the exposed edge and forms a *facet* of the gem. There are three forms of cutting—the *brilliant*,



The brilliant. The rose.

* A carat is equal to 4 gr. Troy. The term is derived from the name of a bean which, when dried, was formerly used by diamond merchants in India as weights.

the *rose*, and the *table*. The brilliant has a flat surface on the top, with facets at the side, and with facets below terminating in a point, so arranged as to refract the light most brilliantly. This form shows the stone to the best advantage, but is used only in large, thick stones, as it sacrifices nearly half the weight in cutting. The rose is flat beneath, while the upper surface is ground into triangular facets, terminating at a common vertex. The table form is used only for thin specimens, which are merely ornamented by small facets on the edge. The diamond is valued not alone for its rarity and high refractive power, by which it flashes such vivid and brilliant colors, but also for its mechanical uses. For cutting glass, the curved edges of the natural crystal are used.

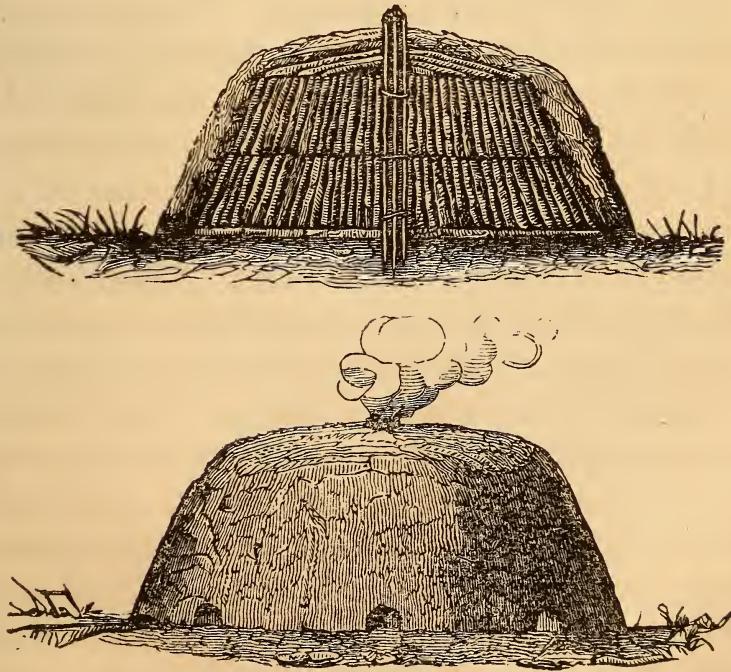
GRAPHITE or PLUMBAGO is also called black-lead, because on paper it makes a shining mark like lead. It is found at Ticonderoga, N. Y., and at Brandon, Vt. It is supposed to be of vegetable origin.

Uses.—It is chiefly useful in pencils. For this purpose a mixture of black-lead, antimony, and sulphur—the proportion of these ingredients determining the hardness of the pencil—is melted and cast into blocks, which are then sawed into thin slips, as seen in common pencils. For drawing-pencils, pure graphite powder is subjected to such enormous pressure that the particles are brought near enough together for the attraction of cohesion to hold them in a solid form, when the pressure is removed. This solid block is then sawed into prisms as before, and fitted into

cylinders of cedar-wood. Though graphite seems very soft, yet its particles are extremely hard, and the saws used in cutting it soon wear out. We notice the same fact in sharpening a pencil with a knife. Graphite mixed with clay is made into black-lead crucibles. These are the most *refractory* known, and are used for melting gold and silver. It is also sold as "British lustre," "carburet of iron," "stove polish," etc., which are employed for blacking stoves and protecting iron from rusting.

GAS-CARBON is formed on the interior of the retorts used in coal-gas works. It has a metallic lustre, and will scratch glass.

CHARCOAL.—This is formed by burning piles of



Making charcoal.

wood, covered over with turf, so as to prevent free access of air. The volatile gases, water, etc., are driven off, and the C left behind. This forms about $\frac{3}{4}$ of the bulk of the wood and $\frac{1}{4}$ its weight. Charcoal for gunpowder and for medicinal purposes is prepared by heating willow or black alder in iron retorts.

Properties.—It is the most unchangeable of all the elements, so that even in the charcoal we can trace all the delicate structure of the plant of which it was made. It is insoluble in any liquid. None of the acids, except nitric, corrode it. No alkali will eat it. Neither air nor moisture affects it. Wheat has been found in the ruins of Herculaneum that was charred 1800 years ago, and yet the kernels are as perfect as if grown last harvest. The ground end of posts are rendered durable by charring. Indeed some were dug up not long since in the bed of the Thames which were placed there by the ancient Britons to oppose the passage of Julius Cæsar and his army. A cubic inch of fine charcoal has 100 feet of surface, so full is it of minute pores. These absorb gases by capillary attraction to an almost incredible extent. A bit of C will take up 90 times its bulk of ammonia. As the various gases and the O of the air are brought so closely together within its pores, rapid chemical changes are produced, as in the case of platinum black, of which we have already spoken. Fresh provisions are packed in C for long voyages, and hams have been thus kept sweet for years. Foul water filtered through C loses its impurities. Beer

by this process parts not only with its color but with its bitter taste. Ink is robbed of its value and comes out clear and transparent as water.

Deoxydizing Action of C.—At a high temperature the appetite of C for O is insatiable. It will take it out in the heat of a furnace from almost the stablest compounds. Upon this fact depends its use in the arts. Nearly all the ores and many of the elements are locked up in the rocks with O, and C is the key expressly made by the Creator for unlocking the treasure-houses of nature for the supply of our wants. By noticing the process of preparing zinc, iron, phosphorus, etc., we shall see the importance of this property of C. A very pretty illustration is shown by placing a few grains of litharge (PbO), or the oxyd of any metal, on a flat piece of charcoal, and directing upon it the flame of a blow-pipe. The metal will immediately appear in little sparkling globules.



Litharge on charcoal.

Soot is unburnt carbon which passes off from a lamp or fire when there is not enough O present to combine with all the C of the fuel. This, therefore, comes away in flakes, and blackens the chimney of the lamp, or lodges in the chimney of the house. After a time it gathers in sufficient quantity, and we are startled by the cry, "The chimney is on fire!" while with a great roar and flame the soot burns out. This unpleasant occurrence is much more frequent when green wood is used for fuel. The HO of the

wood absorbs much of the heat of the fire, and so permits the C to pass off unconsumed.

LAMPBLACK is obtained by imperfectly burning pitch or tar. The dense cloud of smoke is conducted into a chamber lined with sacking, upon which the soot collects. It is largely used in painting. It is mixed with clay to form black drawing-crayons, and with linseed oil to make printers' ink. Lampblack or charcoal has peculiar properties which fit it for printing. Nothing in nature could supply its place. No matter how finely it is pulverized, it retains its dead-black color. The minutest particle is as black as the largest mass. No chemical agents will change it. It never decays. The paper may moulder—we may even burn it, and still, in the ashes, can we trace the form of the printed letter. The ancients used an ink composed of gum-water and lampblack, and manuscripts have been exhumed from the ruins of Pompeii and Herculaneum which are yet perfectly legible.

ANIMAL CHARCOAL, or bone-black, is made by burning bones in close vessels. Mixed with oil of vitriol, it forms paste-blacking. Common vinegar filtered through it becomes the colorless white vinegar of the pickle manufacturers. It is largely used by sugar refiners. Brown sugar is dissolved in HO, and the solution filtered through animal charcoal. This removes all the impurities which constitute the coloring matter. The solution is then slowly evaporated in "vacuum pans," and the sugar collects in clear white crystals.

MINERAL COAL.—This was formed in a former period of the world's history, called the Carboniferous Era. At that time the world was pervaded by a genial tropical climate. The air was denser and richer with vegetable food than now. The earth itself was a swamp, moist and hot, in which plants that creep at our feet to-day, or are known only as rushes or grasses, grew to the height of lofty trees, and simple ferns towered into trunks a foot and a half in diameter. These fern-forests resounded with no song of bird or hum of insect; but a strange and grotesque vegetation flourished with more than tropical luxuriance. In these swamps accumulated a vast deposit of leaves and fallen trunks which, under the water, gradually changed to charcoal. In the process of time the earth settled at various points, and floods poured in, bringing sand, pebbles, clay, and mud, filling up all the spaces between the trees that were standing, and even the hollow trunks themselves. The pressure of this soil and the internal heat of the earth combined to expel the gases from the vegetable deposits, and convert them into mineral coal. Where this process was nearly complete, anthracite coal, and where only partially finished, bituminous coal, was formed. The greater the pressure, the harder and purer the carbon produced; unless, however, the covering was not sufficiently porous to allow the gases to escape, when bituminous coal was the result. In time this section was elevated again, and another forest flourished, to be in its turn

converted into coal. Each of these alternate elevations and depressions produced a layer of coal or of soil. In these beds of coal we now find the trunks of trees, the outlines of trailing vines, the stems and leaves of plants as perfectly preserved as in a herbarium, so that, to the botanist, the flora of the Carboniferous era is as complete as that of our own.

COKE is the refuse of gas-works, obtained by distilling off all the water, tar, and volatile gases from bituminous coal. It is burned in locomotives, blast-furnaces, etc.

PEAT is an accumulation of half-decomposed vegetable matter in swampy places. It is produced mainly by a kind of moss which gradually dies below as it grows above, and thus forms beds of great thickness. Sometimes, however, plants may grow in the form of a turf, and decay, thus collecting a vast amount of vegetable *débris*. This gradually undergoes a change, and becomes a brownish black substance, loose and friable in its texture, resembling coal, but, unlike it, containing 20 to 30 per cent. of O. These peat-beds are of vast extent. One-tenth of Ireland is covered by them. One, near the mouth of the River Loire, is said to be fifty leagues in circumference. In Massachusetts and in New York peat is becoming of commercial value, and is used as a fuel in large quantities. For this purpose it is cut out in square blocks and dried in the sun. In many beds it is first finely pulverized, then pressed into a very compact form like brick.

MUCK is an impure kind of peat, not so fully carbonized, though the term is frequently applied to any black swampy soil which contains a large quantity of decaying vegetable matter. Like charcoal, it absorbs moisture and gases, and is therefore used as a fertilizer.

VARIOUS FORMS AND USES OF CARBON.—We have seen in what contrary forms carbon presents itself. It is soft enough for the pencil-sketch, and hard enough for the glazier's use. Black and opaque, it expresses thought on the printed page: clear and brilliant, it gleams and flashes in the diadem of a king. In lampblack it frequently takes fire spontaneously; in graphite, it resists the heat of the fiercest flame; in the diamond, it is an insulator, while in charcoal, it is so perfect a conductor of electricity, that it is packed about the foot of lightning-rods to complete the connection with the earth. We burn it in our lamps, and it gives us light; we burn it in our stoves, and it gives us heat; we burn it in our engines, and it gives us power; we burn it in our bodies, and it gives us strength. As fuel, it readily unites with O, yet we spread it as stove-polish on our ironware to keep the metal from rusting. It gives firmness to the tree and consistency to our flesh. It is the valuable element of all fuel, burning oils, and gases. Thus it supplies our wants in the most diverse manner, illustrating in every phase the forethought of that Being who fitted up this world as a home for his children. Infinite Wisdom alone would

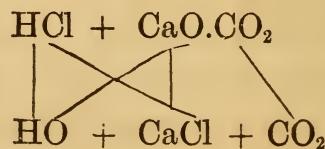
have stored up such supplies of fuel and light, and hidden them far under the earth away from all danger of accidental combustion, or anticipated all the requirements alike of luxury and the arts.

CARBONIC ACID.

Symbol, CO_2 Equivalent, 22 Specific Gravity, 1.52.

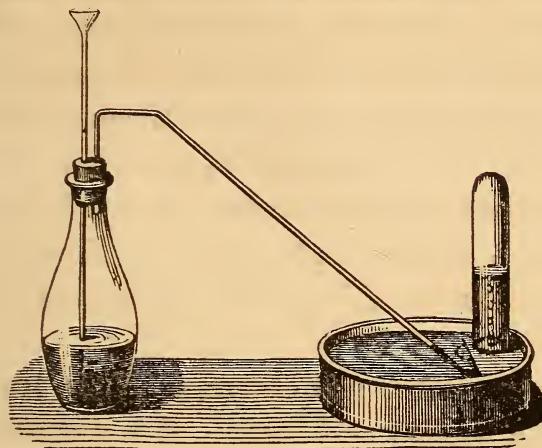
Sources.—It is found combined with lime, as in limestone, marble, chalk, and also in a large class of salts, known as the carbonates, forming nearly one-half of their weight, and almost one-seventh of the crust of the earth. It comprises $\frac{1}{1000}$ part of the atmosphere. It is produced throughout nature in immense quantities. Wherever C burns, in fires, lights, decay, fermentation, volcanoes—in a word, in all those various forms of combustion of which we spoke under the subject of O, where that gas unites with C, carbonic gas is the result. Each adult exhales about 140 gallons per day. Each bushel of charcoal, in burning, produces 2500 gallons.

Preparation.—For experimental purposes it is prepared by pouring HCl (hydrochloric acid) on marble or chalk. The reaction is as follows :



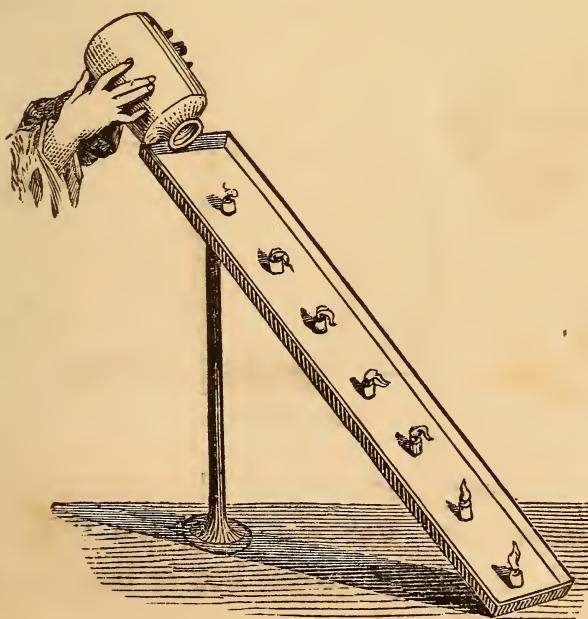
The H of the hydrochloric acid unites with the O of the lime (CaO), forming HO. The Cl of the acid

combines with the Ca of the lime, forming chloride of calcium, while the CO_2 is driven off. It may be



Making carbonic acid.

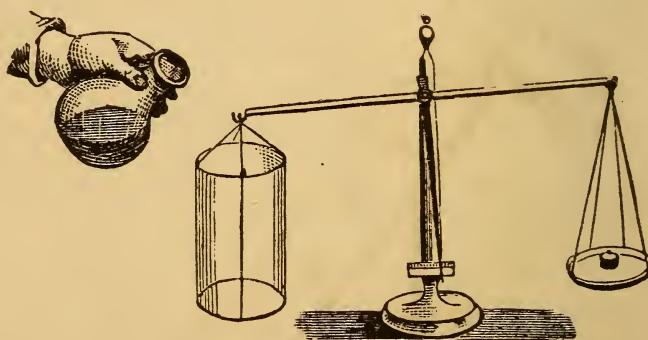
collected in bottles by displacement, or as represented in the cut.



Pouring CO_2 down-hill.

Test.—Its test is clear lime-water. If we expose a saucer of lime-water to the air, its surface is soon covered with a thin pellicle of carbonate of lime, thus showing that there is CO₂ in the atmosphere; or if we breathe by means of a tube through lime-water, the solution will become turbid and milky, thus proving the presence of CO₂ in our breath: by breathing through the liquid a little longer it will become clear, as the carbonate of lime will dissolve in an excess of CO₂.

Properties.—It is a colorless, odorless, transparent gas, with a slightly acid taste. It is a non-supporter of combustion, will run down an inclined plane, and can be poured from one dish to another, and dipped up with a bucket like water, or be weighed in a pair of scales like lead. Example: The accompanying



Weighing CO₂.

cut shows a very neat way of illustrating several of these properties. For weighing, the CO₂ may be contained in a large paper box or bag, such as is used by grocers.

Poisoning by CO₂.—This gas is fatal to life. When largely diluted it acts as a narcotic, producing languor, and finally insensibility and death. It accumulates in wells and cellars, and many persons have been poisoned by descending into such places incautiously. The test of lowering a lighted candle should always be employed. If that is extinguished, your life would be in danger of “going out” in the same way, should you descend. The gas may be dipped out like water, or the well may be purified by lowering pans of slacked lime, or lighted coals

Candle in jar of CO₂.

which, when cool, will absorb the noxious gas. The coals may be rekindled, and lowered repeatedly until the result is reached. A well, in which a candle would not burn within 26 feet of the bottom, was thus purified in a single afternoon. Persons have been poisoned by burning charcoal in an open furnace in a closed room. In France, it is not unusual to commit suicide in this manner. The antidote is to bring the sufferer into the fresh air, and dash cold water upon his face. In the celebrated *Grotto del Cane*, in Italy, the gas accumulates near the floor, so that a man living near amuses visitors, for a small fee, by leading his dog into the cave. He experiences no ill effects himself, but the dog soon falls senseless. A dash of cold water revives him, and



A candle in CO₂.

he is ready to pick up his bone and enjoy the reward of his scientific experiment. The celebrated Upas tree of Java seems not to be altogether fabulous. The poison is not derived from the tree itself; but is due to the fact that it is located in a deep valley about a half-mile in circumference, in which CO₂ is evolved in quantities sufficient to contaminate the entire atmosphere. The valley is said to be strewn with the bones of animals and birds which have strayed into this gaseous lake.

CO₂ in Mines.—Miners call CO₂ *choke-damp*. It is produced by the explosion of *fire-damp* (light carburetted hydrogen) which accumulates in deep mines, and burns with a shock like gunpowder, forming dense volumes of CO₂, which instantly destroys the lives of all who may have escaped the flames of the explosion. Where CO₂ alone is found, it is not considered as dangerous as the *fire-damp*, since it will not burn, and it is said that miners will even venture “where the air is so foul that the candles go out, and are then relighted from the flame on the wick by swinging them quickly through the air, when they burn a little while and then go out, and are relighted in the same way.” CO₂ has been used for the purpose of extinguishing fires in coal-mines. In one case an English mine had burned for 20 years, consuming a seam of coal over a space of 26 acres, defying all attempts to quench it. 8,000,000 cubic feet of CO₂ were poured into it day and night for three weeks, when the mine was cooled with water; and at last, at the close of

the month, the mine was ready for labor to be resumed.

Absorption of CO₂ by Liquids.—Water dissolves its own volume of CO₂ under the ordinary pressure of the atmosphere; but with increased pressure, it will absorb a much greater amount. “Soda water” is improperly named, as it contains no soda, but is simply water saturated with CO₂ in a copper receiver strong enough to resist the pressure of 10 or 12 atmospheres. This gas gives the HO a pleasant, pungent, and slightly acid taste, and by its escape, when exposed to the air, produces a brisk effervescence. In beer, ginger-pop, cider, wine, etc., the CO₂ is produced by the fermentation going on within. The gas escapes rapidly through cider and wine, and so produces only a sparkling; while in a thick, viscid liquid, like beer, the bubbles are partly confined, and so cause it to foam and froth. In canned fruits, catsup, etc., the souring of the vegetables produces CO₂, which sometimes drives out the cork or bursts the bottles with a loud report, scattering the contents far and wide.

Liquid CO₂.—By a pressure of 40 atmospheres, at a temperature of 32°, CO₂ becomes a colorless liquid, very much like water. When this liquid is brought out into the air, it evaporates so rapidly that a portion is frozen into a snowy solid which burns the flesh like a red-hot iron. By means of liquid CO₂, which has a temperature of — 150° F., mercury can be frozen even in a red-hot crucible. Mixed with ether,

and evaporated under the exhausted receiver of an air-pump, Professor Faraday obtained a cold of 166° below zero.

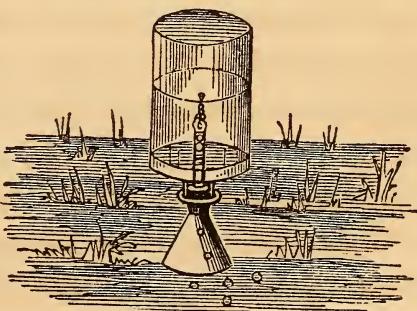
Ventilation.—The relation of carbonic acid to life is most important, and cannot be too often dwelt upon. We exhale constantly this poisonous gas, each person contaminating at least 10 cubic feet of air per minute. If means are not provided to furnish us fresh air constantly, we are compelled to re-breathe that which our lungs have just expelled. The languor, the sleepiness we feel in a crowded assembly, is the natural effect of this narcotic poison. The idea of drinking in at every breath the exhalations that load the atmosphere of a crowded, promiscuous assembly, is disgusting as it is noxious. We shun impurity in every form; we dislike to wear the clothes of another, or to eat from the same dish; we shrink from contact with the filthy, and yet sitting in the same room inhale their poisonous breath. Health and cleanliness alike require that we should carefully ventilate all public buildings, our school-rooms, and our sleeping-apartments. Fresh air and good water are the cheapest luxuries of life, and alas! too commonly the rarest.

Singular Truth.—It is a fact, as poetical as it is characteristic, that when the CO_2 comes forth from the lungs it is poisonous, fully charged with the seeds of disease, so that if we should re-breathe it, death would inevitably ensue; yet as it passes out it produces all the tones of the human voice, all songs, and

prayers, and social conversation. Thus the gross and deadly is by a divine simplicity made refined and spiritual, and caused to minister to our highest happiness and welfare.

CARBONIC OXYD (CO).—This is a colorless, almost odorless gas. It burns with a pale, blue flame, absorbing an atom of O from the air, and becoming CO₂. It is seen thus burning in our coal-stoves, and at the top of tall furnace-chimneys. It is caused by an insufficient supply of O. It is a deadly poison, and escaping from coal-fires in a close room has often produced death. The offensive odor which comes out on opening the door of our coal-stoves is caused by the compounds of sulphur mixed with the CO.

LIGHT CARBURETTED HYDROGEN (C₂H₄).—This is the gas we have already spoken of under CO₂, as the dreaded fire-damp of miners. It is colorless, tasteless, odorless, and burns with a yellowish flame. It is formed in swamps and low marshy places by the decomposition of vegetable matter, and on stirring the mud beneath, will be seen bubbling up through the water. It rises from



Marsh-gas.

the earth in great quantities at many places. At Fredonia, N. Y., it is collected and used in lighting the village. At Kanawha, Va., it is employed as fuel for evaporating the brine in the manufacture of salt.

In the oil-wells of Pennsylvania, it frequently bursts forth with explosive violence, throwing the oil high into the air.

HEAVY CARBURETTED HYDROGEN (C_4H_4).—*Olefiant Gas.*—This is a colorless gas, with a sweet, pleasant odor, and burns with a clear white light.

ILLUMINATING GAS consists principally of the two gases just named. The proportion of the latter, or olefiant gas, which gives the clearness and whiteness to the flame, determines its value. It is made by heating bituminous coal in large iron retorts until coke only is left, and all the volatile constituents are driven off.* These are very numerous. Among them are coal-tar, ammonia, carbonic acid, carbonic oxyd, nitrogen, compounds of sulphur, light and heavy carburetted hydrogen. This mixture is first cooled in the *condenser*, which is a series of iron tubes surrounded by cold water, in which the coal-tar is deposited, with the ammoniacal liquids. Then it is sprinkled with a spray of water, which takes out all the ammonia, and last of all passed through milk of lime, which absorbs the carbonic acid. The remaining gases form the mixture we call “gas.” This is then collected in the gasometer, the weight of which forces it through all the little gas-pipes, and up to every jet in the city. Its unpleasant odor, and the danger resulting from its escape in our rooms, are the same we have just mentioned in coal fires.

CYANOGEN (Cy ,— NC_2).—If we mix hides, horns, etc.,

* A ton of Cannel coal will yield 15,000 feet of gas.

with carbonate of potash and iron filings, and heat them in a close vessel, the N and C of these animal substances in their nascent state will combine, forming cyanogen. This unites with the iron and potassium, forming the beautiful yellow crystals of ferrocyanide of potassium, or so-called *yellow prussiate of potash*. The compounds of cyanogen are named cyanides, and are all made from this salt.

HYDROCYANIC ACID (HCy).—Prussic acid, as it is commonly called, is a most fearful poison. A single drop on the tongue of a large dog is said to produce instant death. Ammonia, cautiously inhaled, is its antidote. Its bitter flavor is detected in peach blossoms, the kernels of plums or peaches, bitter almonds, and the leaves of wild cherry.

FULMINIC ACID.—This compound of Cy is known only as combined with the various metals forming fulminates, which are fearfully explosive. (The term *fulminate* is from the Latin *fulmen*, a thunderbolt.) Fulminating mercury was used to fill the bombs with which the life of Napoleon III. was attempted in 1858. It is employed in making gun-caps. A drop of gum is first put in the bottom of the cap, over which is sprinkled a little fulminating mercury, and this is sometimes covered with varnish to protect it from the moisture.

COMBUSTION.

Combustion, in its popular sense, is the union of a substance with O, and includes all the various forms

of oxydation we named when treating of that gas. The amount of heat depends upon the quantity of O which enters into combination.

Example: HO = 9. Hence, in 9 lbs. of HO there are 8 lbs. of O, and 1 lb. of H. On the other hand, CO₂ = 22. Hence, in 22 lbs. of carbonic acid there are 6 lbs. of C and 16 of O; 1 lb. of C unites with 2½ lbs. of O. Therefore, H combines with three times as much O as C does, and so gives off three times as much heat. The intensity of the heat depends upon the rapidity with which the fuel unites with O. So we open the draft, or blow a fire, to furnish this active element of the air in greater abundance.

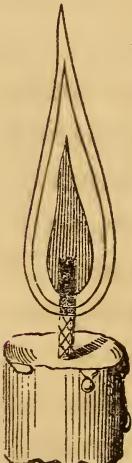
The Igniting Point.—Although O unites at all temperatures, yet combustion, in its popular sense, does not commence until the heat of the combustible is raised to a certain point, when we say "it has caught fire." The burning point of any substance is the temperature at which it bursts into quick combustion. We elevate the heat of a small portion to the point of rapid union with O, and that part in burning will give off heat enough to support the combustion of the rest. Example: In making a fire, we take a substance for kindling which unites with O at a low temperature, as paper or shavings, with which we obtain heat enough to start the combustion of something that requires a higher temperature, as chips or pine sticks, and thus gradually increase the degree of heat until we reach the igniting point of

coal or wood. If we pour on much coal when the fire is low, we will put it out, because the fresh fuel lowers the heat below the point of union with O, which is about 1000° .

CHEMISTRY OF A FIRE.—All our fuel and lights, such as wood, coal, oil, tallow, etc., consist mainly of C and H, and are, therefore, called *hydrocarbons*. In burning, they unite with the O of the air, forming HO and CO₂. These both pass off, the one as a vapor, the other as a gas. In a long stove-pipe, the HO is sometimes condensed, and drips down, bringing soot upon our carpets. Ashes comprise the mineral matter contained in the fuel, united with some of the CO₂ produced in the fire. When we first put fuel in the stove, the H is liberated with some C, in the form of carburetted hydrogen gas. This burns with a flame. Then, the volatile H having passed off, we have left the C, which burns as a coal merely. In maple there is much more C than in pine, so it forms a good “bed of coals.” In the burning of fuel there is no annihilation; but the HO, CO₂, and the ashes, weigh as much as the wood and the O that combined with it. No matter how rapidly the fire burns, in the blaze of the fiercest conflagration, the elements unite in exact chemical equivalents. Carbon is most wisely fitted for fuel, since the product of its combustion is a gas. Were it not so, our fires would be choked, and before each supply of fresh fuel we would be compelled to remove the ashes that filled the stove. In the case of a

candle it would be still more annoying, as the solid product would fall around our rooms in an acid shower that would corrode every thing it touched. Still another property is the infusibility of carbon. Did it melt like zinc or lead on the application of heat, how quickly in a hot fire would the coal and wood melt, and run down through the grate and out upon the floor in a liquid mass! These properties, together with its abundance, exactly adapt it to our use.

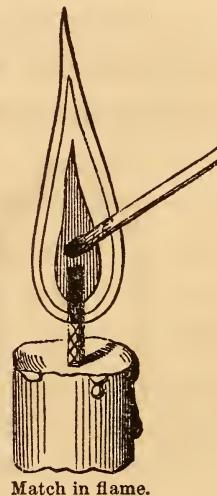
CHEMISTRY OF A CANDLE.—Flame is burning gas. A candle is a small “gas-works,” and its flame is the same as that of a “gas-burner.” First we have a



little cupful of tallow melted by the heat of the fire above. The ascending currents of cool air which supply the light with O₂ also keep the sides of the cup hard, unless the wind blows the flame downward, when the banks break, there is a *crevasse*, and our candle runs down. Next, the melted tallow is carried by capillary attraction up the small tubes of the wick into the flame. There it is turned into gas by the heat. Flame is always hollow, and at the centre, near the wick, is the gas just formed. If a match be placed across a flame, it will burn off at each side in the ring of the flame, while the centre will be unblackened. The gas may be conducted out of the flame by a small pipe, and burned at a little distance from the candle. The flame is hollow

Form of flame.

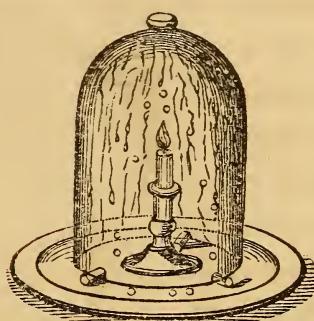
because there is no O at the centre. The gas floats outward from the wick. It comes in contact with the O of the air, and the H, requiring least heat to unite, burns first, forming HO. This produces heat enough to make the tiny particles of C, floating around in the flame of burning H, white-hot. They each send out a delicate wave of light, and passing on to the outer part, where there is more O, burn, forming CO₂. The flame is blue at the bottom, because there is so much O at that point that the H and C burn together, and so give little light. The HO may be condensed on any cold surface. The CO₂ may be tested by passing the invisible smoke of a candle through lime-water. The wick of a candle does not burn because of the lack of O at the centre. It, however, is charred, as all the volatile gas is driven off by the heat. If a portion falls over to the outer part, where there is O, it burns as a coal. If we blow out a candle quickly, we can see the gas passing off, and can relight the candle with an ignited match held at some distance from the wick. The tapering form of the flame is due to the currents of air that sweep up from all sides toward it. The candle must be snuffed, because the long wick would cool the blaze below the igniting point of C and O, and the C would pass off unconsumed. A draught of air, or any cold substance thrust into the flame,



Match in flame.

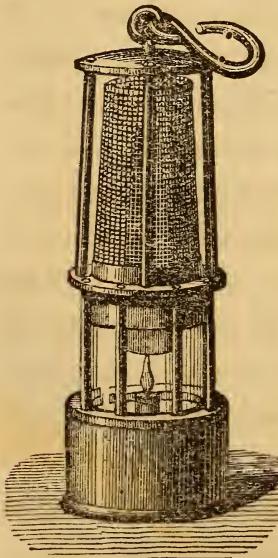
produces the same result, and deposits the C as soot. Plaited wicks are sometimes used, which, being thin, fall over to the outside and burn, requiring no snuffing.

CHEMISTRY OF A LAMP.—A chimney confines the hot air and makes a draught of O through the flame.



Water in a flame.

A flat wick is used, as it presents more surface to the action of the O. Argand lamps are made with a hollow wick, so as to admit O into the centre of the blaze. The film which gathers on a chimney when we first light a lamp, is the HO produced in the flame, condensed on the cold glass. A pint of oil forms a full pint of HO. Spirits of turpentine, tar, pine-wood, etc., contain an excess of C, and not enough H to heat it to the point of union with O. These, therefore, produce clouds of soot. Alcohol contains an excess of H and little C, hence it gives off great heat and but little light. Davy's Safety Lamp, used by miners, consists of an ordinary oil-lamp, surrounded by a cylinder of fine wire-gauze. Even if the flame of the lamp is thrown against the outside, or inflam-



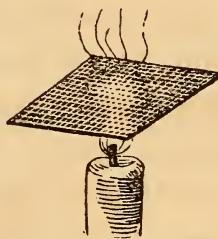
Davy's Safety Lamp.

mable gases from the mine come into the inside, the wire conducts off the heat, and reduces it below the point of union with O, so no flame can pass through, and no gas on the outside ignite.

Through carelessness fearful accidents have occurred, even since this lamp has been used. Miners become extremely negligent, and an account is given of an explosion, in which about a hundred persons were killed, caused by a lamp being hung on a nail by a hole broken through the wire-gauze.

EXTINGUISHING FIRES.—Blowing on a candle or lamp extinguishes it, because it lowers the heat of the flame below the point of union of C with O. Fires are put out by HO partly for the same reason, and also because it envelops the wood and shuts off the air. If a person's clothes take fire, the best possible remedy is to wrap him in a blanket, carpet, coat, or even in his own garments. This smothers the fire, by shutting out the O of the air. Great care should be taken in a fire not to open the doors or windows, so as to cause a draught of air. The entire building may burst into a blaze, when the fire might have been confined for want of O, and so easily extinguished.

SPONTANEOUS COMBUSTION.—Sometimes chemical changes take place in combustible substances, whereby heat enough is generated to cause ignition. Lime occasionally absorbs HO, so as to set fire to



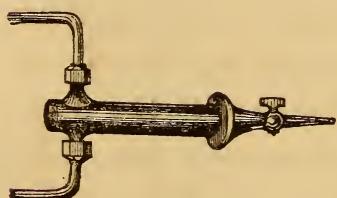
Wire-gauze in flame.

wood in contact with it. Fresh-burned charcoal has the power of absorbing gases in its pores so vigorously as to become ignited. Heaps of coal often take fire from the iron pyrites contained in them being decomposed by the moisture of the air. The waste cotton used in mills for wiping oil from the machinery, is thrown into large heaps, and absorbs O from the air so rapidly that it often bursts into a blaze. Instances have been given of the human body itself taking fire spontaneously. It happens most generally in the case of intemperate persons. In these instances the fire was not easily subdued nor communicated to other substances,—the body having even burned to ashes while the garments were unconsumed.

OX-HYDROGEN BLOW-PIPE.*—In the Compound Blow-pipe a jet of O is introduced into the centre of a jet of burning H, producing a *solid flame*.

Inasmuch also as H unites with so much O, an immense heat is developed. A watch-spring will burn in it with a shower of sparks. Platinum, the most infusible of metals,

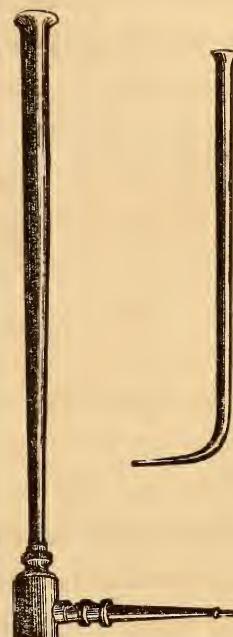
requiring a temperature of 4591° , or over twenty times that of boiling water, readily melts. In the common hollow flame, as we have seen, the little



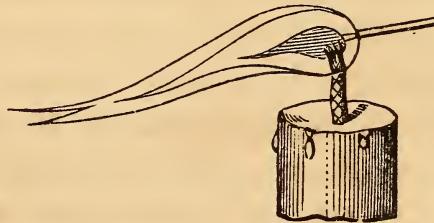
* See Frontispiece.

particles of solid C, heated by the burning H, produce the light. As there is no solid body in the Blow-pipe flame, it is scarcely luminous. If, however, we insert in it a bit of lime, a most dazzling light is produced. This is called the "Drummond," "Lime," or "Calcium" Light, and has been seen at a distance of one hundred and eight miles in broad sunlight.

Blow-pipe.—In the common blow-pipe, used by jewellers, a current of O from the lungs is thrown into the centre of an alcohol blaze. It is thus rendered solid and its heat greatly increased. Near the extreme point of the flame the unconsumed gases are very hot, and combine readily with the O of any substance inserted into the flame at that part, which is therefore called the "*reducing flame*." Just at the point of the flame, the O thrown from the lungs is highly heated, and is ready to combine with any substance, and is therefore called the "*Oxydizing flame*." Example: Hold a copper cent in the flame of an alcohol lamp.

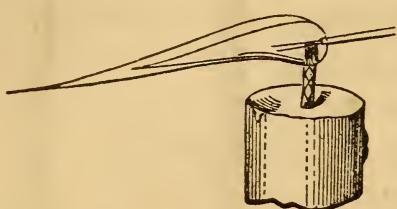


Common Blow-pipe.



Reducing flame.

In the "reducing flame" its rust or oxyd of copper will be all cleaned off, and the cent will shine as brightly



Oxydizing flame.

as if just from the mint.

In the "oxydizing flame" the various oxyds of copper will be formed over the surface, and so the most beautiful play of colors will flash from side to side

as we move the cent from one part to the other.

THE ATMOSPHERE.

The "air we breathe" consists of N, O, CO₂, and watery vapor. The first composes $\frac{4}{5}$, the second $\frac{1}{5}$, the third $\frac{1}{1000}$, and the last a variable proportion. The N and O form so large a part, that they are considered in ordinary calculation to compose the whole atmosphere. A very clear idea of the proportion of these several constituents may be formed by conceiving the air, not as now dense near the surface of the earth, and gradually becoming rarified as we ascend to its extreme limit of 50 miles, but of a density throughout equal to that which it now possesses near the earth. The atmosphere would then be but about five miles high. The vapor would form a sheet of HO over the ground five inches deep, next the CO₂ a layer of 13 feet, then the N a layer of one mile, and last of all, the O a layer of four miles. (*Graham.*) In this arrangement we have supposed the gases to be placed in the order of their specific gravity. The

atmosphere is not thus composed in fact, the various gases being equally mingled throughout, in accordance with a principle called the "*Law of the Diffusion of Gases.*" If we throw a piece of lead into a brook, it will settle instantly to the bottom by the law of gravitation, and remain there forever by the law of inertia. But if we throw out into the atmosphere a quantity of CO₂, it sinks for an instant, then immediately begins to mingle with the surrounding air, and is soon entirely dissipated. Example: If we invert an open-mouthed bottle full of H over another full of CO₂, in a few hours the H, light as it is, will have crawled down into the lower jar; and the CO₂, heavy as it is, will have crawled up into the upper jar; and the gases will be found equally mixed. By this law the proportion of the elements of the atmosphere is the same everywhere, and has not varied within historic times. Samples have been analyzed from every conceivable place, from polar and torrid regions, from prairies and mountain-tops, from balloons and mines, and even from bottles-full sealed up in the ruins of Herculaneum, and the result is the same. These gases do not form a chemical compound, but a mere mechanical mixture, and they are as distinct in the air as so many grains of wheat and corn mingled in a measure. Each of these has its separate use and mission. The action of O and N we have already seen.

Uses of CO₂.—This bears the same relation to vegetable that O does to animal life. The leaf—the

plant-lungs—through its million of little *stommatæ*, or mouths, drinks in the CO₂. In that minute leaf-laboratory, by the action of the sunbeam, the CO₂ is decomposed, the C being applied to build up the plant, and the O returned to the air for our use. Plants breathe out O as we breathe out CO₂. We furnish vegetables with air for their use, and they in turn supply us. There is thus a mutual dependence between the animal and the vegetable world. Each relies upon the other. Deprived of plants we would soon exhaust the O from the air, supply its place with CO₂, and die; while they, removed from us, would soon exhaust the CO₂, and die as certainly. We poison the air while they purify it. Each tiny leaf and spire of grass is thus imbibing our foul breath, and returning it to us pure and fresh.* This interchange of office is so exactly balanced, that, as we have seen, the proportion of CO₂ and of O never varies. “Two hundred million tons of coal are now annually burned, producing six hundred million tons

* In connection with this subject it is well to notice that the current idea, that plants exhale CO₂ at night, is now known to be erroneous. They purify the air while the sunlight shines upon them, and in darkness are at rest. Plants in a room are, therefore, healthy, unless they are of such varieties as emit a poisonous odor. Certainly the freshness and cheeriness given to an apartment by a stand of flowers, or even a few pots in a window-bench, must delight all; while the refining influence of the beautiful in nature would suggest the propriety of adorning our dwellings in this simple manner, did not chemistry teach its practical utility as a mode of purifying the air.

of CO₂. A century ago, hardly a fraction of that amount was burned, yet this enormous aggregate has not changed the proportion in the least." (*Youmans*.)

Use of Watery Vapor.—We have already seen the uses of HO. As vapor, it is everywhere present and ready to supply the wants of animals and plants. Were the air dry, our flesh would shrivel into that of a mummy, and leaves would wither as they do in an African simoom. Rivers and streams flow to the ocean; yet all their fountains are fed by the currents that move in the air above us. HO rises in the air as vapor, flows on to colder regions, falls as rain, dew, snow, or hail, and then working as it goes whatever it finds to do, moistening a plant or turning a water-wheel, it finds its way back to the ocean. Thus Niagara itself must first have risen to the clouds as vapor before it can fall as a cataract.

PERMANENCE OF THE ATMOSPHERE.—Did the elements readily unite to form nitric acid, instead of, as now, with great difficulty, and only in a thunder-storm, we would be constantly exposed to a shower of this corrosive acid that would be destructive to all vegetation, clothing, and even our bodies themselves.—O and N have never been solidified or liquefied by the severest cold or pressure, while CO₂ requires a force that is never reached in nature. Watery vapor, on the contrary, is deposited as dew or rain by a slight change of temperature; this is necessary to supply the wants of vegetation and life. But were the same true of the other constituents,

they would come raining down upon us in most disastrous showers; and in winter we would be compelled to melt what air we should need, and carry a supply with us constantly. Life itself would be unendurable under such circumstances. Again, the permanence of the air produces all the uniformity of sound. Were the proportions of the atmosphere to change, all "familiar voices" would become strange and uncouth to us, while the harmonies of music would shock us with unwonted discord. If, by some means, the air of a concert-room could be changed to H, for instance, the bass voices would become irresistibly comic and shrill, while the tenor would emulate railway whistles. It is pleasant to notice how each element of the air is adapted for a special work, and all fitted to the present order of nature.

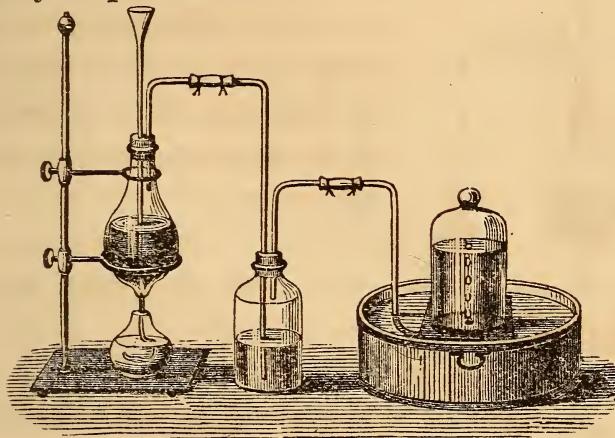
THE HALOIDS.

Chlorine	Symb., Cl;	Equiv., 35.5 ;	Spec. Grav.,	2.47
Iodine	" I;	" 126.8 ;	"	2.47
Bromine....	" Br;	" .80 ;	" (at 30°),	3.18
Fluorine....	" Fl;	" .19 ;	"	1.31

These four elements are closely allied, and form a class of compounds known as the *haloid salts*, from *halo*, salt, because they resemble common salt.

CHLORINE is named from its green color. It is chiefly found in common salt, of which it forms 60 per cent., and is made by moderately heating it with black oxyd of manganese, sulphuric acid, and water. This mixture liberates the gas in great quantities.

It is heavier than common air, and so may be collected by displacement.

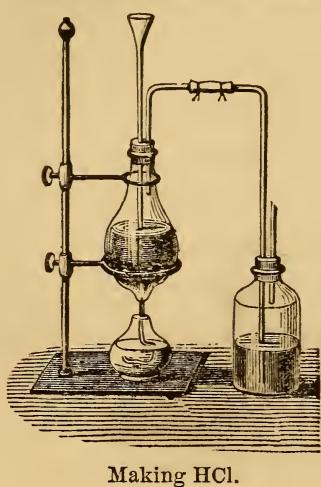


Making Chlorine.

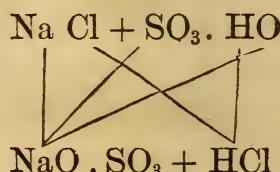
Properties.—It has a greenish-yellow color, and a peculiarly disagreeable odor. It produces a suffocating cough, which can be relieved by breathing ammonia or ether. Arsenic, antimony, Dutch gold-leaf, phosphorus, etc., combine with it so rapidly as to inflame;—powdered antimony producing a shower of brilliant sparks when slowly dropped into a jar of Cl. Cold water absorbs about twice its volume of the gas, which soon turns to hydrochloric acid (HCl) in the sunlight. It has such a powerful affinity for H, that it will even attract it out of a moist organic body, and form HCl. It acts thus upon turpentine, depositing its C in great flakes of soot. It discharges the color of indigo, ink, wine, etc., almost instantaneously. It has no effect on printers' ink, as that contains no H.



Turpentine
in Cl.

HYDROCHLORIC ACID (HCl)—*Muriatic Acid*.—When

Cl and H are mixed and exposed to the direct sunlight they unite with an explosion. In the arts, HCl is prepared from sulphuric acid and common salt.



Properties.—It is an irrespirable, irritating, acid gas, with an intense attraction for HO, which causes it to produce white fumes in the air. Water absorbs 480 times its bulk, forming the liquid known as “*Muriatic Acid*.” It unites with the metals, and forms chlorides. When pure it is colorless, but has ordinarily a yellow tinge, due to various impurities. Its tests are ammonia, with which it forms a white cloud of sal-ammoniac fumes, and nitrate of silver, from which it precipitates chloride of silver. With NO₅ it forms aqua-regia, or *royal water*, so named because it dissolves gold, the “king of the metals.” It sets free chlorine, which, in its nascent state, attacks the gold and combines with it.

CHLORIDE OF LIME (*Bleaching Powder*).—This is prepared by passing a current of Cl over pans of

fresh slacked lime. It is much used in bleaching and as a disinfectant.

Bleaching.—In domestic bleaching the cloth is first boiled with strong soap, to dissolve all the grease and wax, and then laid upon the grass, being frequently wet to hasten the action of the air and sun. The dew seems to have a peculiar influence, while the corrosive ozone of the atmosphere doubtless aids in the process. The H of the coloring matter unites with the O of the air or dew, forming HO, and thus destroying the coloring compound. This was essentially the process long pursued in Holland, where all linens were formerly carried for bleaching: hence the term “Holland linen,” still in use. The HO about Haarlem was thought to have peculiar properties, and no other could compete with it. Cloths sent there were kept the entire summer, and were returned in the fall. Later a similar plan was adopted in England. But the vast extent of grass-land required, the time occupied, and the temptation to theft, made the process extremely tedious and expensive. The statute laws of that time abound in penalties for cloth stealing. It is estimated that all the men, women, and children in the world could not, by the old way, bleach all the cloth that is now used. At present the cloth is well washed, and boiled in water with strong alkalies, to remove the grease, &c.; next it is passed through a solution of chloride of lime, and lastly through diluted SO₃. In this step the SO₃ unites with the lime, and sets free

the Cl, which in turn combines with the H of the coloring matter, forming HCl, and thus bleaches the cloth most perfectly. About twenty-four hours are required for this process, and the cost is not quite a cent per yard. Paper rags are bleached in the same way in paper-mills. Stains can be removed from *uncolored cloth* by a little chloride of soda (Labarraque's Solution), which can be obtained of any druggist. Place the cloth in this liquid, and if obstinate, pour on a little boiling HO, or place it in the sun for some hours. Then rinse thoroughly in cold HO, and dry.

Disinfectant.—Chlorine is a powerful disinfectant. It breaks up the offensive substance by uniting with its H, as in bleaching. Other disinfectants, as burnt paper, sugar, etc., only disguise the ill odor by substituting a stronger one. In the sick-room Cl is set free from chloride of lime by exposing it to the air in a saucer with a little HO. The gas soon passes off, though the process may be hastened by adding a few drops of dilute SO₃. A handful of chloride of lime, thrown under the floor, will vanquish even a dead mouse, or any other odoriferous domestic animal, living or dead.

BROMINE—named from its bad odor—is a poisonous, volatile, deep-red liquid, with the general properties of Cl. It is principally found in sea-water, and forms bromides with the metals, which are used in photography.

FLUORINE is the only element that will not unite

with O, and for this reason exists in the enamel of the teeth. It is found in Derbyshire or fluor spar (Ca.FI), of which beautiful ornaments are made. It unites with H, forming hydrofluoric acid (HFI), noted for its corrosive action on glass. This eats out the silica or sand from the glass, and is therefore used for etching labels on glass bottles and names on shop-windows. Example: Powdered fluor spar is placed in a lead tray, and covered with dilute SO₃. The heat of a lamp applied beneath, for a moment only, liberates the gas in white fumes very rapidly. The plate of glass is covered with wax, and the design to be etched is traced upon it with a sharp-pointed instrument. This is then laid over the tray, and the escaping gas soon etches the lines laid bare into an appearance like ground glass. A solution of HFI in HO is often sold for this purpose. It is kept in lead or gutta-percha bottles, combines with HO with a hissing sound, like red-hot iron, and must be handled with care, as a minute drop even will sometimes produce an incurable ulcer.

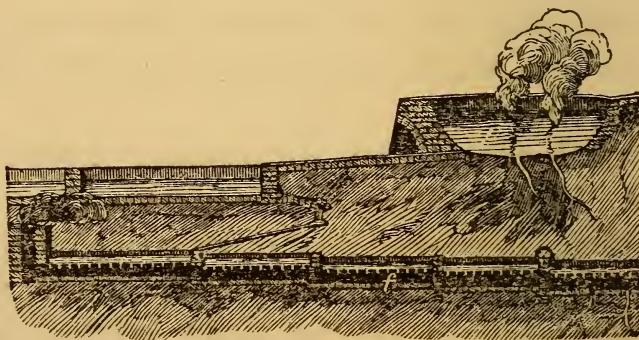
IODINE is named from its beautiful violet-colored vapor. It is made from kelp—the ashes of sea-weed, and is found in sea-water and in some mineral springs. It has a bluish-black, metallic appearance, and is sparingly soluble in HO, but readily in ether or alcohol. It inflames spontaneously when in contact with phosphorus. Its compounds with the metals, called the iodides, are remarkable for their variety and bril-

liancy of color. It stains cloth a yellowish tint, which may be removed by a solution of iodide of potassium. Its test is starch, forming the blue iodide of starch. It reveals the presence of this substance in potatoes, apples, etc. It is much used in medicine to scatter scrofulous or cutaneous eruptions and swellings.

BORON.

Symbol, B Equivalent, 10.9.

BORON is known in nature only in combination with O, as boracic acid (BO_3). This is found in the volcanic districts of Tuscany. Here, for an area of about 30 miles, is a wild, mountainous region, of terrible violence and confusion. The surface is ragged and blasted. Everywhere there issue from the ground jets of steam, filling the air with most offensive odors. The earth itself shakes beneath the feet, and frequently yields to the tread, engulfing man and



Preparing BO_3 .

beast. "The waters below are heard boiling with strange noises, and are seen breaking out upon the

surface. Of old, it was regarded as the entrance to hell. The peasants pass by in terror, counting their beads and imploring the protection of the Virgin." In the midst of this scene of horror a most lucrative business has been established. These jets of steam are charged with boracic acid. A series of basins are excavated up the sides of the principal mountain. These are filled with cold HO from the neighboring springs. Into these basins the jets of steam are conducted. The HO absorbs the boracic acid, and becomes itself heated to the boiling-point. It is then drawn off into the next lower basin. This process is continued until the bottom one is reached, when the HO runs into leaden pans heated by the steam from the earth; here the HO is evaporated, and the boracic acid is collected. 3,000,000 lbs. are sold per annum.

BORAX is a biborate of soda ($\text{NaO} \cdot 2\text{BO}_3$). It is employed largely in welding. It dissolves the oxyd of the metal, and keeps the surface bright for soldering. It softens hard water by uniting with the soluble salts of lime or magnesia, and making insoluble ones which settle and form a thin sediment in the bottom of pitchers in which it is placed.

SILICON.

Symbol, Si Equivalent, 14.

Sources.—This is commonly found in combination with O, as silicic acid, silica, silex or quartz (SiO_2). It composes 45 per cent. of the crust of the earth.

It forms beautiful crystals and some of the most precious gems. When pure, it is transparent and colorless, as in rock-crystal. Jasper, amethyst, agate, chalcedony, opal, topaz, chrysoprase, sardonyx, etc., are all common flint-stone or quartz, colored with some metallic oxyd. Sand is mainly fine quartz, which, when hardened and cemented, we call sand-stone. Yellow or red sand is colored by iron-rust.

Properties.—It is tasteless, odorless, and colorless. It seems very strange to call such an inert substance an acid; yet it is a *true acid*, since it unites with the alkalies, neutralizes their properties, and forms a large class of salts known as the silicates, which are found in the most common rocks—Example: granite.

SILICA IN SOIL AND PLANTS.—Silica is insoluble in HO, unless it contains some alkali. When the silicates, so abundant in rocks, disintegrate and form soil, the alkali and silica are both dissolved in the water, and taken up by the roots of plants. We see the silica as grit in maple-sugar, or as deposited on the surface of scouring-rushes or sword-grass, on which we have so often cut our fingers. It gives stiffness to the stalks of wheat and other grains, and produces the hard, shiny surface of bamboo, corn, etc.

PETRIFICATION.—Certain springs contain large quantities of some alkali; their waters, therefore, dissolve silica abundantly. If we place a bit of wood in them, as fast as it decays, particles of silica will take its place—atom by atom—and thus petrify the

wood. The wood has not been *changed* to stone, but has been *replaced by* stone.

SULPHUR.

Symbol, S Equivalent, 16 Specific Gravity, 2.

Sources.—Sulphur is found native in volcanic regions. It is mined at Mount \AA etna in great quantities. Combined with the metals it forms sulphurets, known as cinnabar, iron pyrites, etc. Combined with SO_3 it exists in gypsum (plaster), heavy spar, and other sulphates. It is found in the hair, and many dyes contain lead which unites with this S, and forms a black compound that stains the hair. It is contained in eggs, and so tarnishes our spoons by forming a sulphuret of silver. It is always present in the flesh, and hence manifests itself in our perspiration ; with some persons it is so abundant as to produce a disagreeable odor. In commerce it is sold as brimstone, formed by melting S and running it into moulds ; also as flowers of sulphur, obtained by *sublimation*.

Properties.—It is insoluble in HO, and hence tasteless, although when taken in molasses it seems otherwise. Its solvent is bisulphide of carbon, but it will dissolve somewhat in oil of turpentine. It is a non-conductor of heat, and crackles when we grasp it with a warm hand. It manifests itself under three allotropic forms : 1st, octohedron crystals ; 2d, prismatic crystals ; 3d, an amorphous (without form) or uncristallized state. The last is the most interesting. Example : If sulphur be melted, and

then heated up to 480° , it changes into a thick, viscid, dark-colored liquid like molasses, which, if poured into cold water, is elastic like india-rubber. In this form it is used for taking impressions of medals, coins, &c.

SULPHUROUS ACID (SO_2), an irrespirable, suffocating gas, is formed by S burning in the air, as in the lighting of a match. It is very poisonous, and extinguishes combustion. If our "chimney burns" at any time, we can easily quench the flame by pouring a little S into the stove. Its compounds are called sulphites.

Uses.—It is used for bleaching silk, straw, and woollen fabrics. Cl cannot be used for these substances, as it turns them yellow, but SO_2 unites with the coloring matter, and forms a colorless compound. Its action is therefore very different from that of Cl. Example : A red rose, bleached in the fumes of burning S, can be restored to its original color by a little very dilute SO_3 . This acid being stronger, neutralizes the action of the SO_2 . New flannels, washed in strong soap, turn yellow, because the alkali of the soap unites with the SO_2 used in bleaching the cloth, and thus sets free the original color.

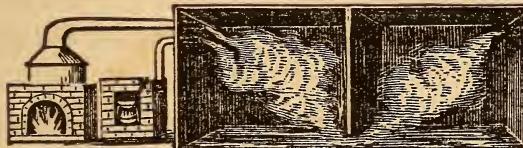
SULPHURIC ACID (SO_3)—*Oil of Vitriol, the "King of the Acids."*—This acid is of the utmost importance to the manufacturer and chemist, as it is used in the preparation of nearly all other kinds, forming many valuable compounds. The acid of the shops

is a strong solution of the gas in HO. Its compounds are called sulphates.

Preparation.—Example: If in a jar we burn a little S, it will soon become filled with the fumes of SO₂. One atom of O added to this SO₂ would make it SO₃. It will be remembered that NO₅ easily parts with its O. Now if we stir the fumes with a swab wet with NO₅, we will notice that the white gas in the jar turns red, and will recognize the old “nitrous acid fumes,” and on testing we will find SO₃ in the jar, especially if there be any HO at the bottom to absorb it. The nitric acid has turned the SO₂ into SO₃. This is essentially the plan pursued in its manufacture on a large scale. An immense chamber, perhaps three hundred feet in length, is lined with lead and intersected by perforated leaden partitions to mix the gases more thoroughly as they pass through. In this are

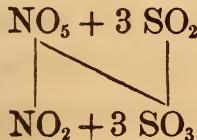


Making SO₃ and SO₂.



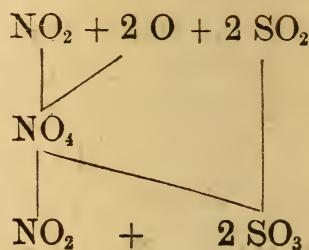
Manufacture of SO₃.

admitted steam, fumes of burning sulphur, and nitric acid, from furnaces at the side.



The NO₅ gives up 3 atoms of O to 3 atoms of SO₂, thus making 3 atoms of SO₃, and

becoming itself NO_2 . Not content with the work now done, in its anxiety to supply the wants of the SO_2 , the NO_2 goes to the air present in the room, takes up 2 atoms of O, becoming NO_4 , and flies back with them



to the SO_2 , making 2 atoms more of SO_3 , then turns to the air again for a fresh supply. It thus carries the O back and forth to such an extent that a small quantity of NO_5 , introduced in the beginning, will make an almost unlimited amount of SO_3 . The steam hastens the chemical operation by its warmth and moisture. There is a thin layer of HO on the floor. This absorbs the SO_3 , and is gradually drawn off and condensed by evaporation in lead pans, and finally, when the SO_3 begins to corrode the lead, in large platinum vessels. It is lastly put in large bottles packed in boxes called *carboys*, when it is ready for transportation.

Properties.—It is a dense oily liquid, without odor, and of a brownish color. It freezes at 30° and boils at 640° . It is a hydrate, containing one atom of HO to one of SO_3 , thus $\text{SO}_3 \cdot \text{HO}$. Its affinity for moisture is most remarkable. If exposed in an open bottle it gradually absorbs the water of the air, and increases in bulk. It will in time double its weight in this way. It blackens wood and other organic

substances, by taking away their HO and leaving the C. When SO₃ is mixed with HO, it occupies less space than before, and liberates much heat; 4 parts of acid to 1 of HO will boil a test-tube of HO. It commonly contains lead, which falls as a milky precipitate when the acid is mixed with HO. It is the strongest of the acids, and will displace the others from their compounds. It stains cloth red, but the color can be restored with any alkali;—NaO. CO₂ is best. Its test is chloride of barium, which forms a beautiful white cloudy precipitate. In this way a drop of SO₃ in a quart of HO can be distinctly detected. Experiment: Strong oil of vitriol poured on a little loaf-sugar moistened with hot water, will cause an energetic boiling and a copious formation of black charcoal. Sugar consists of water and charcoal, and gives up all the former to satisfy the appetite of the SO₃.

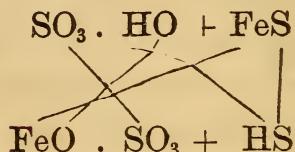
NORDHAUSEN ACID is the ancient *oil of vitriol* made in Germany from green vitriol. It is the strongest sulphuric acid known, and may be separated from its HO by distillation, when the acid will appear as white silky flakes, which may be handled with impunity, and will hiss when thrown into HO.

SULPHIDE OF HYDROGEN (HS)—*Sulphuretted Hydrogen*.—This gas is produced in the decay of organic matter, and is always found near cesspools, drains, and sinks, turning the paint black and emitting a disagreeable smell. It gives the characteristic odor to the mineral waters of Avon, Clifton, Sharon, and

Saratoga. It is prepared by the action of dilute SO₃ upon sulphuret of iron.



Making HS.



It has the disgusting odor of rotten eggs, is very poisonous, and, therefore, makes an open sewer very destructive to health. Its solution in HO is much used in the laboratory to precipitate the metals as a black sulphuret. Its test is acetate of lead (sugar of lead).

BISULPHIDE OF CARBON (CS₂) is produced by passing the vapor of S over red-hot coals. It is a volatile, colorless liquid, and has never been frozen. It is strange that a yellow odorless solid should unite with a black odorless solid to form such a colorless odorous liquid; it thus illustrates very finely the

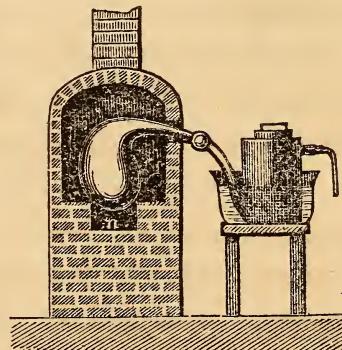
power of chemical affinity. It readily dissolves sulphur, phosphorus, and iodine. It is a powerful refractor of light, and is used for filling hollow glass prisms—the most perfect known—for experiments with the solar spectrum.

PHOSPHORUS.

Symbol, P Equivalent, 31 Specific Gravity, 1.83.

Its name signifies *light-bearer*, given because of its glowing in the dark. It was called by the old alchemists, “the son of Satan.”

Sources.—It exists in small quantities in rocks, and by their decay passes into the soil, is taken up by plants, is then stored in their seeds (wheat, corn, oats, etc.), and finally passes into our system. As a phosphate of lime, it is the principal constituent of our bones. As pure P, it is so necessary to the operation of the brain that the alchemists had a saying, “No phosphorus, no brains.”



Manufacture of P.

Preparation.—It is prepared in immense quantities from bones. These are first calcined to whiteness to burn out the animal matter, then treated with SO_3 to remove the lime, and lastly heated to a high temperature with C to deoxydize them, when the P distils as a vapor, which is condensed under HO .

Properties.—It is a waxy, transparent solid, at all temperatures above 32° emits a feeble light, and at 60° bursts into a flame. It is therefore so combustible that it should be handled with the utmost care, always kept and cut under HO, and never used except in very small quantities. Its burns are deep and dangerous. It is very poisonous, and is the basis of all rat-exterminators. Its vapor produces horrible ulcerations of the jaw-bone in workmen who use it. In burning, it unites with five atoms of O, forming phosphoric acid (PO_5). Its compounds are called phosphates.

Amorphous Form.—Heated for 48 hours, at a temperature of 480° , in a close vessel, P is changed into a brick-red powder, which seems to have lost all the properties of P. It can be handled with impunity, and carried in the pocket like so much snuff. By heating it again to a higher point, it goes back to its old form.

Uses.—**MATCHES.**—The principal use of P is in the making of matches. The match is first dipped in melted sulphur and dried, then in a paste of P, nitre and glue, which completes the process. The object of the nitre is to furnish O to quicken the combustion. Instead of this, chlorate of potash is sometimes used, and can be recognized by the crackling sound and jets of flame when ignited. The tips are colored by red-lead, or Prussian blue, mixed in the paste. When a match is burned, the reaction is as follows: first, the friction ignites the P, which burns, forming

PO_5 ; this produces heat enough to inflame the S, which makes SO_2 ; lastly, the wood takes fire, and forms CO_2 and HO. Thus there are four compounds produced in the ignition of a single match. During the burning of the S, the value of the match is entirely prospective, as the SO_2 is not a supporter of combustion.

PHOSPHORESCENCE.—The luminous appearance of putrefying fish and decayed wood are well known. The latter is sometimes called “fox-fire.” The “glow-worm’s fitful light” is associated with our memory of beautiful summer evenings. In the West Indies, fire-flies are found that emit a green light when resting, and a red one when flying. These are so brilliant that one will furnish light enough for reading. The natives wear them for ornaments on their bonnets, and illuminate their houses by suspending them as lamps.—The ocean, at times, takes on strange colors, and the sailor finds his vessel plowing at one time apparently a furrow of fire, and at another one of liquid gold. The water is all aglow, and the flames seem to leap and dance with the waves or the motion of the ship. These phenomena are produced by multitudes of animalculæ which frequent certain seas. Phosphorescence is generally attributed to the gradual oxydation of the phosphorus secreted by the animal or plant.

PHOSPHURETTED HYDROGEN (PH_3) is formed in the decomposition of bones and organic substances. With HS it gives rise to the odor of slaughter-houses. It

is a poisonous gas, remarkable only for its disgusting odor and the singular beauty of the rings formed by its smoke ascending through the air. It is prepared by dropping bits of phosphuret of calcium into HO. It has been thought by some that the Will-o'-wisp, Jack-o'-the-lantern, etc., as seen near graveyards and in swampy places, is produced by this gas coming off from decaying substances, and igniting as it reaches the air.

THE METALS.

THE METALS OF THE ALKALIES.

These are *potassium*, *sodium*, *lithium*, and *ammonium*. The last two are of no general interest.

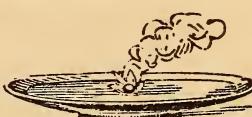
POTASSIUM.

Symbol, K Equivalent, 39 Specific Gravity, 0.85.

Source.—This metal was discovered by Sir Humphrey Davy, in 1807, by the decomposing action of a powerful galvanic battery. By passing the current through potassa (KO), the K went to the negative pole, and the O to the positive. In the same manner he separated the metals sodium, barium, strontium, and calcium. This discovery constituted a most important epoch in chemistry. K is found abundantly in nature in the various rocks which, by their decom-

position, furnish it to the plants, from whence we obtain our entire supply.

Properties.—It is a silvery-white metal, soft like wax, and light enough to float like cork. Its affinity for O is so great, that it is always kept under the surface of naphtha, which contains no O. K, when thrown on HO, decomposes it, unites with its O, forming KO, and sets free the H. The heat developed is so great, that the H catches fire and burns with some volatilized K, which tinges the flame with a beautiful purple tint. If the HO be first colored with red litmus, it will become blue by the alkali (KO) formed.



Potassium on water.

POTASSA (KO)—*Potash.*—This is a grayish-white solid, made from KO.CO₂ by the action of lime. It is the most powerful alkali. It neutralizes the acids, and turns red litmus to blue. It is used to cauterize the flesh, and is hence commonly called “caustic potash.” It dissolves the cuticle of the finger which touches it, and so has an unctuous feel, as we see in strong soap. It unites with grease, forming soap, and is extensively used for that purpose. Its affinity for HO is so great, that it is never known except as a hydrate (KO.HO). It also absorbs CO₂ from the air, and must be kept in close-stoppered bottles. It is a corrosive, deadly poison. Its test is bichloride of platinum, forming a yellow precipitate from a solution.

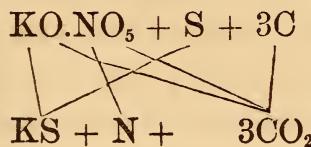
CARBONATE OF POTASH (KO.CO₂)—*Pearlash.*—Pot-

ash is contained in plants, combined with various acids, such as tartaric, malic, oxalic, etc. When the wood is burned, the CO_2 of the fire drives off these acids, and combines with the KO, forming KO.CO_2 . The ashes are then leached, and the *lye* which is formed is evaporated until the KO.CO_2 crystallizes. Birch gives the purest potash, while the leaves furnish 25 times as much as the heart of a tree. Where wood is abundant, immense quantities are burned solely for the ashes. *Saleratus* is a bicarbonate of potash (KO.2CO_2), and is formed by passing a current of CO_2 through the carbonate.

NITRATE OF POTASH (KO.NO_3)—*Saltpetre*: *Nitre*.—This salt is found abundantly in Egypt and the East Indies, mixed with the soil. It is obtained thence by leaching. It is formed artificially by piling up great heaps of mortar, refuse of sinks, stables, etc. In about three years these are washed, and each cubic foot of the mixture will furnish four or five ounces of saltpetre. It was manufactured in the Mammoth Cave, Kentucky, during the war of 1812. It dissolves in one-third of its weight of hot water.

Properties and Uses.—It is cooling and an antiseptic: hence it is used for salting meat, to which it gives a reddish tint. It parts with its O readily and burns brilliantly. Every government keeps a large supply on hand for making gunpowder, in the event of war. Gunpowder is composed of three parts charcoal, and one each of saltpetre and sulphur. Its explosive force is due to the expansive power of the

gases formed. The combustion is started by the saltpetre giving up all its O to burn the S and C. The reaction that ensues may be *very simply* stated as follows :



N and CO₂ are gases, and in that great heat of nearly 2,000°, high enough to melt gold or copper, the KS becomes a vapor. With the sudden increase of temperature, they expand till they occupy 2,000 times the space of the powder. The bad odor of burnt powder is due to the slow formation of HS in the residuum. Fireworks are composed of gunpowder ground with additional C and S, and some coloring matter. Zinc filings produce green stars, steel filings variegated ones. A little chlorate of potassa tinges the flame with crimson. Salts of copper give a blue or a green light, and camphor a pure white one.

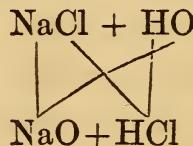
SODIUM.

Symbol, Na Equivalent, 23 Specific Gravity, 0.972.

This metal is found principally in common salt. It is very like K in its appearance, properties, and reaction. When thrown on HO it rolls over its surface like a beautiful little silver ball : if the HO be heated, it bursts into a yellowish blaze. The test of

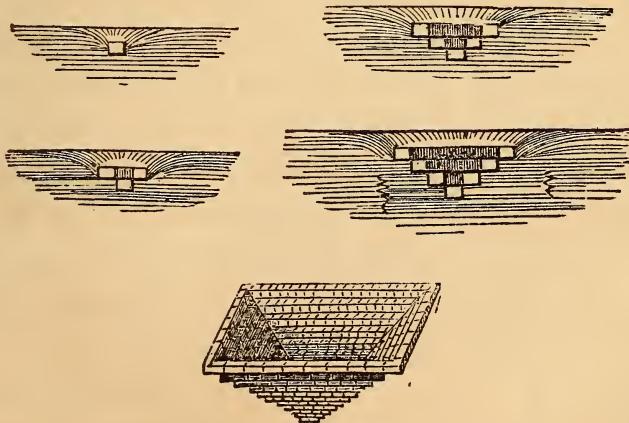
all the soda salts is the yellow tint which their solution in alcohol gives to the flame.

CHLORIDE OF SODIUM (NaCl), *common salt*, is the only mineral substance which is absolutely necessary to the life alike of all human beings and the higher order of animals. Among the many cruel punishments inflicted in China, deprivation of salt is said to be one, causing at first a most indescribable longing and anxiety, and finally a painful death. Dr. Draper tells us that the salt and the HO in the stomach undergo the following reaction :



Both these are essential in forming gastric juice and bile, and to make enough of them to keep up the proper digestion of our food, requires about one-third of an ounce of NaCl . As salt is so universally necessary, it is found everywhere. Our Father, in fitting up a home for us, did not forget to provide for all our wants. The quantity of salt in the ocean is said to be equal to five times the mass of the Alps. Salt lakes are scattered here and there ; saline springs abound ; and besides these, in the earth are stored great mines, probably produced by the evaporation of salt lakes in some ancient period of the earth's history. At Cracow, Poland, is a bed twelve hundred miles long, twenty miles wide, and a quarter

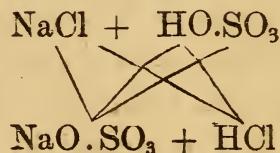
of a mile thick. In Spain, and lately in Idaho, it has been quarried out in perfect cubes, transparent as glass, so that a person can read through a large mass. On the sea-shore it is manufactured by the evaporation of sea-water, each gallon containing about four ounces. At Syracuse, New York, near by and underneath the Onondaga Lake, is apparently a great basin of salt-water, separated from the fresh-water above by an impervious bed of clay. Penetrating this to a depth of about seven hundred feet, the saline water is pumped up in immense quantities. The State sells this to salt manufacturers, on the payment of a cent per bushel on the salt made. The HO is evaporated by heating in large iron kettles or vats, or in the sun, whence the name "solar salt." If boiled down rapidly, fine table-salt is made; if more slowly, coarse salt, as large crystals have time to form. Frequently they assume a "hopper shape"—one cube appears, then others



Hopper Form.

collect at its edges, and gradually settle, until a hollow pyramid of salt-cubes, with its apex downward, is formed. About seven million barrels are made annually at this city. Salt dissolves equally well in hot or in cold water, and a *saturated* solution (one containing all it will dissolve) has 37 per cent. of salt.

SULPHATE OF SODA ($\text{NaO} \cdot \text{SO}_3$), *Glauber's salts*, named from the discoverer, is made from common salt.



Experiment: Make a saturated solution of sulphate of soda, and with it fill a bottle. Either put in the glass stopple or cover the top with a thin layer of oil, and let the bottle stand. The salts will remain for weeks or even months without crystallizing; but if they be taken up, and shaken ever so little, the whole mass will instantly form into crystals, so filling the bottle that not a drop of water will escape, even if it be inverted. Should there be any hesitation in crystallizing at the moment, drop into the bottle a minute crystal of Glauber's Salts, and the effect will instantly be seen in the darting of new crystals in every direction.

CARBONATE OF SODA (NaO.CO_2), *sal-soda*, is used in immense quantities in the manufacture of glass,

soap, etc. (See Appendix, Problem 40.) It is employed, like borax, to soften hard water, by combining with the lime and magnesia, and making insoluble carbonates, which settle to the bottom. In washing, it unites with the grease in the clothes, and forms soap.

BICARBONATE OF SODA ($\text{NaO} \cdot 2\text{CO}_2$) is the “*soda*” of the cook-room, and is formed, like saleratus, from its carbonate.

SILICATE OF SODA AND LIME ($\text{NaO} \cdot \text{SiO}_2 + \text{CaO} \cdot \text{SiO}_2$)—*French plate and window glass.* Glass was known to the ancients. Hieroglyphics, that are as old as the sojourn of the Israelites in Egypt, represent glass-blowers at work, much after the fashion of the present. In the ruins of Nineveh, articles of glass, such as vases, lenses, etc., have been discovered. Mummies, three thousand years old, are adorned with glass beads. The inventor is not known. Pliny tells us that some merchants, once encamping on the sea-shore, found in the remains of their fire bits of glass, formed from the sand and ashes of the sea-weed by the heat; but this is impossible, as an open fire could not be sufficient to melt these materials. In the fourth century, the glass-works at Alexandria produced most exquisite ornaments, with raised figures beautifully cut and gilded. As late, however, as the twelfth century, a house with glass windows was esteemed something magnificent; and we read that in 1577, during Queen Elizabeth’s reign, when the

Duke of Northumberland came to town to pass the winter, the windows of his castle were taken out and packed away for safe-keeping until spring.

Preparation.—Glass is a double silicate, being composed of silica and any two of the alkaline bases, lime, soda, potash, or magnesia. Example: Fine white sand is mixed with sal-soda and lime, and then heated in earthen pots to the most intense degree for forty-eight hours. The materials fuse and form a double silicate of soda and lime. This is common window-glass. A variation in the materials used produces different kinds of glass. The only essential ingredients are sand and soda or sand and potassa. Lime hardens and gives lustre, while soda imparts a green tint. Arsenic whitens it. Oxyd of lead is used in large quantities, as high as one-half the weight, to form a soft glass, which can be ground into imitation gems, table-ware, chandelier pendants, prisms, etc. Oxyd of iron gives an opaque green, as in common junk or green glass bottles. Boracic acid increases the refractive power for lenses in microscopes and telescopes.

Bohemian glass is a silicate of potash and lime, and thus does not show the green tint of soda. Pulverized flint was formerly used for sand, and hence the term *flint-glass*.

COLORED GLASS.—A small quantity of some metallic oxyd, melted with the glass, gives any tint desired: AuO gives a ruby red; MnO , an amethyst; CuO , an azure blue; As and Sb a soft white enamel, as in

lamp-shades; SnO_2 , a hard enamel, as in watch-faces.

ANNEALING GLASS.—If the glass utensils were immediately used, they would be found extremely brittle, and would drop in pieces in the most unaccountable way. The heat of the hand or a draft of cool air would sometimes crack off the thick bottom of a tumbler. They are therefore cooled very gradually for days, which allows the particles to assume their natural place, and the chemical attractions to become equalized. This principle is beautifully illustrated by the chemical toy known as the “Prince Rupert Drop.”

ORNAMENTAL WARE.—Venetian balls or paper weights are made by arranging bits of colored glass in the form of fruits, flowers, etc., and then, inserting this ball into a hollow globe of transparent glass, still hot, the workman draws in his breath, and the pressure of the air above collapses the globe upon the colored glass, and leaves a concave surface in the top of the weight. The lens form always magnifies the size of the figures within.

TUBES AND BEADS.—In making glass tubing, the workman inserts his iron blowing-tube into a pot of melted glass, and gathers upon the end a suitable amount: drawing this out, he blows into the tube, swelling the glass into a globular form. Another dip into the pot and another blow increase its size, until at last a second workman attaches an iron rod to the other end. The two men then separate on a

rapid trot. The soft glass globe diminishes in size as it lengthens, until at last it hangs between them a glass tube of one hundred feet in length, and perhaps only a quarter of an inch in diameter. In making beads, these glass tubes are cut in small bits, and then worked about in a mixture of wet ashes and sand, until they are filled. Next they are put with loose sand into a rapidly-revolving cylinder over a hot furnace. The heat softens the glass, but the mixture within presses out the sides, and the sand grinds the edges, until at last the beads become round and perfect, and are taken out ready for market.

AMMONIUM.

AMMONIUM (NH_4) has never been separated, but is thought to be the base of ammonia (NH_3). In combination NH_3 combines with an atom of HO, becoming $\text{NH}_3 \cdot \text{HO} = \text{NH}_4 \cdot \text{O}$. This is considered as the oxyd of the compound radical ammonium. Example: $\text{NO}_5 + \text{HO} + \text{NH}_3$ uniting, form $\text{NH}_3 \cdot \text{HO} \cdot \text{NO}_5$.

VV
METALS OF THE ALKALINE EARTHS.

These are Ba, Ca, and Mg, but the last two only are of general interest.

CALCIUM.

Symbol, Ca....Equivalent, 20....Specific Gravity, 1.57.

This metal exists abundantly in limestone, gypsum, and, combined with phosphoric acid, in the bones of the body. It is commonly known only as an oxyd-lime.

CaO (CAUSTIC or QUICKLIME) is obtained by heating limestone ($\text{CaO} \cdot \text{CO}_2$) in large kilns. The CO_2 is driven off by the heat, and leaves the lime as a white solid.

Properties.—It is a strong alkali, and corrodes the flesh. Its test is CO_2 , producing a milky precipitate of $\text{CaO} \cdot \text{CO}_2$. It has such a strong affinity for HO, that 28 lbs. of lime will absorb 9 lbs. of HO, forming $\text{CaO} \cdot \text{HO}$, or "slacked lime," and swelling up to three times its original size, with the evolution of much heat. It absorbs HO from the air, and then CO_2 , thus gradually becoming a carbonate of lime—"air-slacked lime." It is more soluble in cold than hot water. A thin film of carbonate of lime will soon gather over a solution of lime exposed to the air.

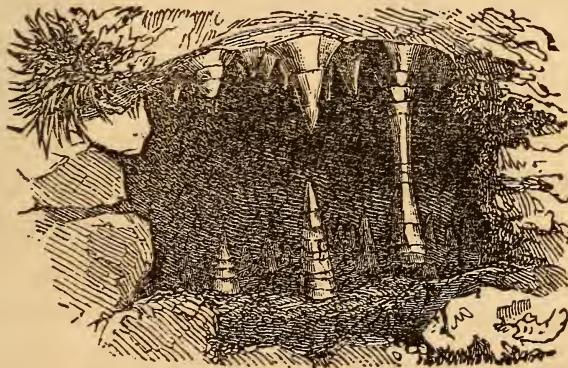
Uses.—It is used in tanning leather to remove the hair. Whitewash is a "milk of lime"—*i. e.*, a mixture of CaO and HO. In mortar, lime hardens rapidly,

in part by uniting with the silica of the sand to form a silicate, and also by absorbing CO₂ from the air to form carbonate of lime. In this process, the HO which the lime absorbed in slackening is given off; this causes the dampness always seen on newly-plastered walls when the room is first warmed. For drying plastering it would be much better if the CO₂ of the fire could be sent directly into the room, as it would hasten the chemical change. "If common mortar be protected from the air it will remain without hardening for many years. It is stated that lime still in the condition of a hydrate has been found in the pyramids of Egypt. When the ruins of the old castle of Landsberg were removed, a lime-pit, that must have been in existence 300 years, was found in one of the vaults. The surface was carbonated to the depth of a few inches, but the lime below this was fresh as if just slacked, and was used in laying the foundations of the new building." (*Am. Cyc.*)

If the lime contains a little clay, it is called *water-lime*, and will harden under water. Lime is valuable as a fertilizer. It acts by rapidly decomposing all vegetable matter, and thus forming ammonia for the use of plants. It also sets free the alkalies that are combined with silica in the soil, and furnishes them to the plants. It does not itself feed the plants, as almost any soil contains enough lime for that purpose. If applied to a compost heap, it will set free ammonia, which can be recognized by the odor: this is its most valuable constituent. The NH₃ can be

saved by sprinkling the heap with *very* dilute SO_3 , or plaster, or by mixing it with dry muck, which will absorb the gas. If there is any copperas (produced by the oxydation of iron pyrites) in the soil, the lime will decompose it, forming gypsum and iron-rust ($\text{CaO} \cdot \text{SO}_3 + \text{Fe}_2\text{O}_3$), thus changing a noxious ingredient into an element of fertility.

CARBONATE OF LIME.—This includes all varieties of common limestone, chalk, marble, marl, and forms the principal part of corals, shells, and bones. Water charged with CO_2 absorbs carbonate of lime freely, which, when the gas escapes on exposure to the air, is deposited. In this manner, in limestone regions, the water trickling down into caverns has



A Cave.

formed "stalactites," which depend from the ceiling, and "stalagmites," that rise from the floor. These frequently assume most curious and grotesque forms, as in the Mammoth Cave. Around many springs, the water, charged with lime in solution, flows over moss or some vegetable substance, upon which the

lime is deposited. The spongy stone thus formed is calcareous tufa, or "petrified moss." *Whiting* is a carbonate of lime, made by grinding chalk. *Marble* is crystallized limestone. *Chalk* or *marl* is a porous kind of limestone, formed from beds of shells, but not compressed as in common limestone. These minute shells may be detected by a powerful microscope, even in glazing scraped from a common visiting card.

SULPHATE OF LIME ($\text{CaO} \cdot \text{SO}_3$)—*Gypsum*, *Plaster*, etc.—This occurs as beautiful fibrous crystals in satin spar, as transparent plates in selenite, and as a snowy-white solid in alabaster. It is soft, and can be cut into rings, vases, etc. When heated it loses its water of crystallization, and falls into powder, called "Plaster of Paris," from its abundance near that city. Made into a paste with HO, it first swells up, and then immediately hardens into a solid mass. This property fits it for use in copying medals and statues, forming moulds, fastening metal tops on glass lamps, etc. Plaster is also used as a fertilizer. Its action is probably somewhat like that of lime, and in addition it gathers up ammonia and holds it for the plant. It is said that Franklin brought it into use by sowing it over a field of grain on the hill-side, so as to form, in gigantic letters, the sentence, "Effects of gypsum." The rapid growth produced soon brought out the words in bold relief, and decided the destiny of gypsum among farmers. *Sulphite* of lime ($\text{CaO} \cdot \text{SO}_2$) should be distinguished from the sulphate ($\text{CaO} \cdot \text{SO}_3$). This is used for preserving cider.

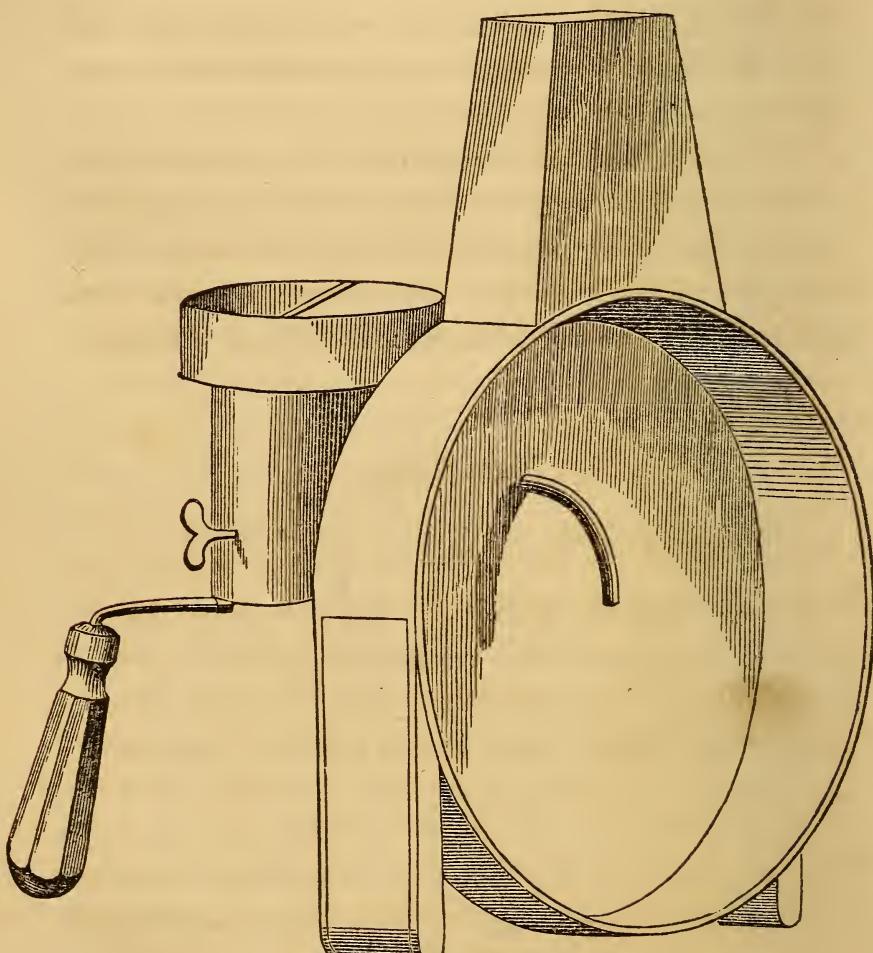
PHOSPHATE OF LIME is contained, as we have already seen, in bones. If now we add to them SO₃, it will take up a part of the lime, making sulphate of lime (plaster), and the phosphoric acid thus driven off will take refuge with the rest of the acid and share its lime, forming a *super-phosphate* of lime. This is used very extensively as a fertilizer, and is, as we have described, a mixture of gypsum or plaster, lime, and phosphoric acid. The last furnishes phosphorus to the growing plant to store in its seeds. Example: Corn, wheat. Phosphate of lime and ammonia are the valuable constituents of "guano."

MAGNESIUM.

Symbol, Mg Equivalent, 12 Specific Gravity, 1.7.

Source.—Mg is found in many rocks as meer-schaum, soapstone, and magnesian limestone, and is abundant also in sea-water. It gives to a stone a soapy feel. When pure, it has a silvery appearance and lustre. It is very light and tenacious as steel, while it is flexible as twine. It burns in the open air with a brilliant white light, casting dense shadows through an ordinary flame. This light possesses the actinic or chemical principle so perfectly, that it is used for taking photographs at night, views of coal-mines, interiors of dark churches, etc. It has every ray of the spectrum, and so does not, as does gas-light, change some of the colors of an object upon

which it falls. Lamps for burning it are very extensively made in Boston. By means of clockwork, the metal, in the form of a narrow ribbon, is fed in front



Magnesium Lamp.

of a concave mirror, at the focus of which it burns. The product of the combustion of Mg is MgO, the very substance from which the metal was obtained.

It is probable that the process of preparation will be cheapened, so that magnesium may be furnished at a rate which will bring it within the scope of the arts. It would be invaluable for lighting stores in which fancy goods are sold, or for illuminating large halls by means of a single lamp suspended in the dome.

CARBONATE OF MAGNESIA ($MgO.CO_2$).—This is the “magnesia alba,” or simple magnesia of the druggists. By driving off the CO_2 , calcined Mg is formed. Sulphate of Mg ($Mg.SO_3$) is known as Epsom salts, from a celebrated spring in England in which it abounds.

METALS OF THE EARTHS.

These are Al, Gl, Zr, Y, Th, Er, Tb, Ce, Ln, D, In, Tl, Rb, Cs. All are extremely rare except the first.

ALUMINUM.

Sym., Al Equiv., 13.7 Spec. Grav., 2.5 Fusing Pt., 2283°.

This is commonly called the “clay-metal.” It is named from alum, in which it occurs. It is the metallic base of all clay, argillaceous, and granite rocks. It is a bright white metal, does not oxydize in the air, nor, like silver, tarnish by HS. It gives a clear musical ring; is lighter than glass, being only two and a half times as heavy as HO; is ductile, malleable, and more tenacious than Fe. It

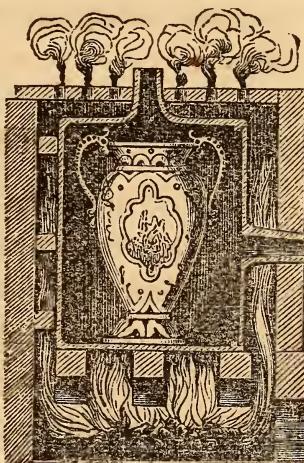
dissolves in HCl or in common vinegar, but is proof against SO₃ or NO₅. On account of its abundance (every clay-bank is a mine of it) and useful properties, it must ultimately come into common use in the arts and domestic life.

ALUMINA (Al₂O₃).—Pure alumina, crystallized in nature, forms valuable Oriental gems. They are variously colored by the oxyds ;—blue, in the sapphire ; green, in the emerald ; yellow, in the topaz ; red, in the ruby. Massive impure crystals, when powdered, are called emery, and are used for polishing.

SILICATE OF ALUMINA (Al₂O₃.SiO₂)—*common clay*.—When the granite rocks decay, by the resistless and constant action of the air, rain, and frost, they crumble into clay. This gives firmness to the soil, and retains moisture, but is cold and tardy in producing vegetable growth. When free from iron, it is used for making tobacco-pipes. When colored by yellow or red oxyd of iron, it is known as ochre, and is employed in painting. Common stone and red earthen-ware are made from impure varieties of clay ; porcelain and china-ware require the finest known. Fire-bricks and crucibles are made from a clay which contains much silica. Fullers' earth is a very porous kind, and by capillary attraction absorbs grease and oil from cloth.

Glazing.—When any article of earthenware has been moulded from clay, it is then baked. The ware is now porous, and would not even hold HO.

A mixture of the coarse materials from which glass is made is then spread over the vessel, and heated, till it melts and forms a perfect glazing upon the clay. NaCl and sand form the glazing on stoneware, jugs, etc. PbO makes a yellowish glaze, which is very injurious, as it will dissolve even in vinegar, and form sugar of lead, a deadly poison. The color of pottery-ware and brick is due to the oxyd of iron present in the clay. Some varieties have no iron, and so form white ware and brick.



Baking Porcelain.

SULPHATE OF ALUMINA AND POTASH ($KO \cdot SO_3 + Al_2O_3 \cdot 3SO_3 + 24HO$).—Alum is formed by soaking clay with SO_3 , in large casks for several months, until the sulphate of alumina is formed, when potassa is added, and the whole mass becomes filled with crystals of the new salt. Instead of KO, other bases are sometimes used, and an iron, soda, or chrome alum is formed. When heated, alum loses its water of crystallization, froths up, and becomes a porous mass, known as “burnt alum.” Alum is soluble in 18 parts of cold water. It is much used in dyeing. It unites with the coloring matter, and binds it to the fibres of the cloth. It is therefore called a mordant (*mordet*, to bite).

ALUM CRYSTALS.—Beautiful octohedron crystals

of alum are obtained by suspending threads in a saturated solution of this salt. In this manner alum-baskets, bouquets, etc., are made of any desired color.

SPECTRUM ANALYSIS.

Many of the metals named as rare have been lately discovered by what is termed Spectrum Analysis. We have already noticed that various metals impart a peculiar color to flame; thus the soda salts give a yellow tinge, copper a green, etc. If now we look at these colored flames through a prism, we shall find the "spectrum," or bands of rainbow-colors we are familiar with, strangely ornamented with bright-tinted lines. Thus the spectrum of sodium has one bright yellow line; silver, two green lines; cæsium, a beautiful blue line. Each metal makes a distinctive spectrum, even when the flame is colored by several substances at once. This method of analysis is so delicate that $\frac{1}{2,736,000,000}$ of a gramme of sodium, or the $\frac{1}{90,000,000}$ of a gramme of lithium, can be detected in the flame of an alcohol lamp.

For the more perfect examination of the spectra, a "spectroscope" is used. This consists of a tube with a narrow slit at one end, which lets only a single ray of colored light fall upon the prism within, and at the other a small telescope, through which one can look in upon the prism and examine the spectrum.

THE HEAVY METALS.

IRON.

Symbol, Fe.... Equivalent, 28.... Specific Gravity, 7.8.

Iron is the symbol of civilization. Its value in the arts can be measured only by the progress of the present age. In its adaptations and employments it has kept pace with scientific discoveries and improvements, so that the uses of iron may readily indicate the advancement of a nation. It is worth more to the world than all other metals combined. We could dispense with gold or silver,—they largely minister to luxury and refinement, while iron represents only the honest industry of labor. Its use is universal, and it is fitted alike for massive iron cables, and for screws so tiny that they can be seen only by the microscope, appearing to the naked eye like grains of black sand.

“Iron vessels cross the ocean,
Iron engines give them motion,
Iron needles northward veering,
Iron tillers vessels steering,
Iron pipes our gas delivers,
Iron bridges span our rivers,
Iron pens are used for writing,
Iron ink our thoughts inditing,
Iron stoves for cooking victuals,
Iron ovens, pots, and kettles,
Iron horses draw our loads,
Iron rails compose our roads,
Iron anchors hold in sands,

Iron bolts and rods and bands,
 Iron houses, iron walls,
 Iron cannon, iron balls,
 Iron axes, knives, and chains,
 Iron augers, saws, and planes,
 Iron globules in our blood,*
 Iron particles in food,
 Iron lightning-rods on spires,
 Iron telegraphic wires,
 Iron hammers, nails, and screws,
Iron everything we use."

Its abundance everywhere indicates how indispensable the Creator deemed it to the education and development of man. There is no "California" of iron. Each nation has its own supply. No other material is so enhanced by labor. A bar of Fe, worth \$5, becomes worth, when made into horse-shoes, \$10; into needles, \$55; penknives, \$3,285; shirt-buttons, \$29,480; and in watch-springs, \$240,000, or more than its weight in gold.

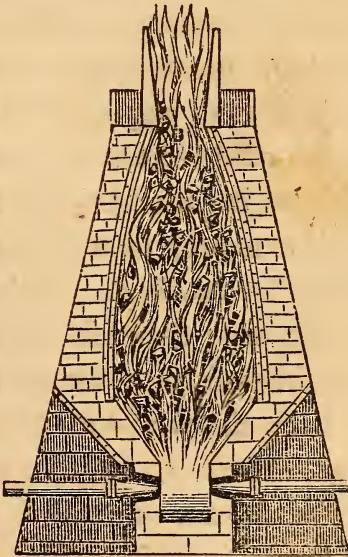
OXYDS OF IRON.—The most usual are: (1) **BLACK OR MAGNETIC OXYD OF IRON** (Fe_3O_4), as found in the loadstone, Swedish iron ore, scales which fly off in forging iron, and in the iron mountains of Missouri. It is also seen in the thin pellicles overstanding HO, producing a beautiful iridescent appearance, the color changing with the thickness of the oxyd: (2) The **RED OXYD OF IRON**—*sesquioxyd*—(Fe_2O_3), as seen in

* There is not probably enough iron in the blood of a full-grown person to make a ten-penny nail, yet it gives energy and life to the system. Iron is given in the form of a fine powder, or a citrate of iron, as a tonic, and is a powerful remedy.

bog-iron ore, in the beautiful radiated and fibrous specimens of brown and red hematite, in bricks and pottery-ware, and in common iron-rust. The sesqui-oxyd, when combined with HO, forms (3) HYDRATED SESQUIOXYP OF IRON ($Fe_2O_3 \cdot HO$), and has a yellow color, which is changed to red by heat, when the HO is expelled, as in burning of brick, etc. These oxyds give the yellow and black colors seen in clayey soils and on the surface of weather-beaten stones. The black gradually oxydizes into the yellow, and so a black stone forms a yellow sand or soil.

Smelting of Iron Ores.—Iron is not found pure, but is locked up with O in an apparently useless stone. C is the key that is ready made and left for our use by the Creator. It only remains for us to apply it and turn the wards.

The process adopted at the mines is very simple. A tall blast-furnace is constructed of stone and lined with fire-brick. At the top is the door and at the bottom pipes for forcing in hot air, sometimes twelve thousand cubic feet per minute, by huge blowing-cylinders driven by steam-power. The furnace is filled with lime, stone, coal, and iron ore, in alternate layers, and the fire ignited. The C unites with



A Blast-Furnace.

the O of the ore, and goes off as CO₂. The limestone forms, with the other impurities, silica, etc., a richly-colored glassy slag, which rises to the top. The melted iron runs to the bottom, and is drawn off into channels cut in the sand on the floor of the furnace. The large main one is called the *sow*, and the smaller lateral ones the *pigs*, and hence the term *pig-iron*.

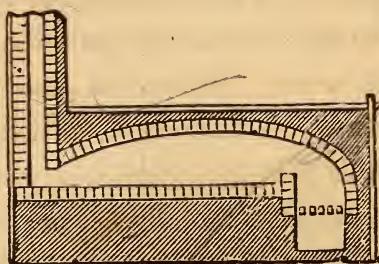
Properties.—Iron when pure is white. As commonly seen it has a gray tint, and is susceptible of a high polish. It is malleable and ductile. It has been beaten into leaves so thin that it has been used for writing-paper—six hundred leaves being only half an inch in thickness—and has been drawn into wire as fine as a hair. By constant jarring it loses its perfect crystalline structure, becoming rotten and brittle, so that the axles of cars, cannon, etc., are condemned after a certain time, although no flaw may appear. It is an exception to the law that “cold contracts,” since at the instant of solidification it expands, so as to copy exactly every line of the mould in which it is cast. This fits it perfectly for castings. Almost the entire value of iron in the arts depends upon this fact. Otherwise we could never hammer out enough tools and machinery to keep the world at work. Was it chance or design that contrived all this nice planning so long even before man was made?

Varieties of Fe.—The usual forms of iron are *cast*, *wrought*, and *steel*. These depend upon the quantity of C they contain. A cwt. of cast-iron has about

5 lbs. of C, a cwt. of wrought about $\frac{1}{2}$ lb., and steel is between them in varying quantities.

CAST FE is the form in which it comes from the furnace. It is brittle, cannot be welded, and is neither malleable nor ductile, but is adapted for castings.

WROUGHT or MALLEABLE FE is made by burning out the C from cast-iron, in a current of highly-heated air, in what is called a reverberatory furnace. The Fe is stirred up constantly, and exposed to the hot air by means of "long puddling-sticks," as they are termed, and then taken out and beaten under a trip-



A Reverberatory Furnace.

hammer to force out all the slag, and bring the particles of Fe nearer each other. It now takes on a fibrous structure, and can be welded, is malleable and ductile. It is hardened by being cooled rapidly, and softened by cooling slowly. The blacksmith tempers his work by plunging the article in cold HO.

STEEL contains less C than cast and more than wrought iron. It is therefore made from the former by taking out a part of the C, or from the latter by heating it in boxes of charcoal, and so adding C.* The value of steel depends largely upon the temper-

* By what is now known extensively as "Bessemer's process of making steel," it is formed from pig-iron without the use of fuel. A current of hot air is carried up through the liquid iron, which burns out the carbon, and in its combustion produces heat

ing quality it possesses. As the metal cools, the film of oxyd on the surface gradually thickens, and so deepens in color. By watching this the workmen know when the exact degree of hardness is reached. Knives require an orange, chisels a crimson, springs and swords a blue tint. Cheap knives made of cast-iron are often covered with a superficial coating of steel. They are simply heated with charcoal a little time, so that the outside only becomes steelified, as it were. When we use such knives, we soon wear through this crust, and find cast-iron beneath, which will take no edge.

Galvanized Fe.—This is formed by dipping sheets of iron in melted zinc, a thin layer of which adheres to the iron and prevents oxydation.

BISULPHURET OF FE (Fe S_2), *iron pyrites*—*fool's gold*; so called, because it is often mistaken by ignorant people for gold. It occurs in cubical crystals and bright shiny scales. It can be easily tested by roasting it on a hot shovel, when we will catch the well-known odor of the S.

SULPHATE OF FE ($\text{FeO} \cdot \text{SO}_3 + 7\text{HO}$)—*green vitriol, copperas*, made at Stafford, Connecticut, from FeS_2 , by exposure to air and moisture. It is formed in the

enough to continue the operation. When the iron is entirely *decarbonized*, enough iron, rich in carbon, called "spiegeleisen," or "looking-glass iron," is added to transform it into steel. At the conclusion, in less than twenty minutes commonly, the entire mass of tons weight is run out and cast into bars of the very best steel. This method has revolutionized the old modes of manufacture.

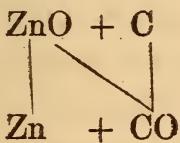
same manner in the decay of rocks, containing iron pyrites, and is found in the soil. Used in dyeing, making ink, and in photography.

ZINC.

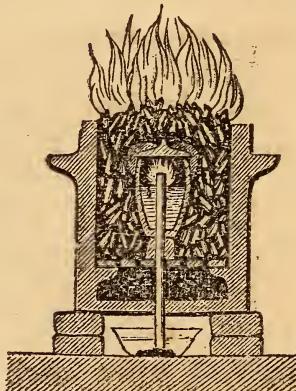
Symb. Zn....Equiv. 32.5....Spec. Grav. 7....Fusing Point, 470° F.

Source.—Zinc, or “spelter” as it is called in commerce, is found in ZnO, or red oxyd, in New Jersey, and as ZnS, or zinc blende, at many places.

Preparation.—ZnO is purified on the same principle as iron ore, by heating the powdered ore with C. The reaction is as follows :



Both these products distil as a vapor, and the Zn is condensed while CO escapes.



Roasting Zinc Ore.

Properties.—Ordinary Zn is brittle, but singularly enough, when heated to 200° or 300° F., it becomes malleable, and is rolled out into the sheet Zn in use so commonly. It burns in the air with a magnificent green light, forming great flakes of ZnO, sometimes called “Philosopher’s Wool.” Example : On a red-hot ladle sprinkle some powdered saltpetre and Zn filings. The KO.NO₅ will furnish O, and the metal will burn with great brilliancy. When exposed to

the air, Zn soon oxydizes, and the thin film of white oxyd, formed over its surface, protects it from further change.

Uses.—It has many economic uses, known to all. The oxyd, ZnO, is sold as zinc-white, and is much valued as a paint, since it is not deleterious to the painters, and does not blacken by HS like white-lead. The sulphate, ZnO.SO₃ (white vitriol), is a powerful emetic.

T I N.

Symb. Sn....Equiv. 56....Spec. Grav. 7.2....Fusing Point, 420° F.

Sn is found mainly in Cornwall, England, in Jackson, New Hampshire, in slight quantities, and in Missouri. It is not ductile, but is very malleable, so that tinfoil is not more than $\frac{1}{1000}$ of an inch in thickness. When quickly bent, it utters a shrill sound, called the "tin cry," caused by the crystals moving upon each other. The tendency of Sn to crystallize is remarkable. Example: Heat a piece of Sn till the coating begins to melt; then cool quickly and clean it in aqua-regia. The surface will be found to be covered with beautiful crystals of the metal. Ordinary tin-ware is formed by dipping sheet-iron in melted Sn, which produces an artificial coating of the latter metal. If we leave HO in a tin dish long, the yellow spots betray the presence of Fe. Tin does not oxydize at ordinary temperatures. SnO₂, sold as *putty powder*, and used for white

enamel and for polishing glass, is formed by the action of NO_5 on Sn. Example: Pour a little dilute NO_5 on scraps of tin, and watch the evolution of nitrous acid fumes, and the formation of SnO_2 . SnS , is the ordinary mosaic gold used in printing the bronze letters and figures on handbills and wall-paper. Pins are made of brass wire, and then boiled with tin and cream of tartar. This gives a bright white surface to the metal. The pins are stuck in papers, as we see them, by machinery which picks them up out of a miscellaneous pile, counts them, and inserts them in the paper, complete for the market. The first part of the process is performed by a sort of coarse comb, which is thrust into the heap, and gathers up a pin in each of the spaces between the teeth.

COPPER.

Symb. Cu....Equiv. 31.7....Spec. Grav. 8.9....Fusing Pt. 1996° F.

Sources.—Found native near Lake Superior, frequently in masses of great size. In these mines are discovered stone hammers, the tools of a people more ancient than the Indians, who probably occupied this continent, and worked the mines. In the Western mounds copper instruments are found. *Malachite*, $\text{CuO} \cdot \text{CO}_2$, is the best known ore of copper. It is found in Siberia, and is worked into beautiful ornaments, much prized by the Russian nobles.

Properties.—It is ductile, malleable, and a con-

ductor of electricity. Its vapor gives a characteristic and beautiful green color to flame. It is hardened by hammering, and softened by heating and plunging into cold HO,—just the reverse of iron, which fact spoils all our good theories as to the cause in either case. In a damp atmosphere, the CO₂ unites with it, forming CuO.CO₂, familiarly but improperly called *verdigris*. The *true verdigris* is *acetate of CuO*, and is produced when we soak pickles in brass or copper kettles; the green color which results is simply this salt—a deadly poison. Preserved fruits, etc., should never stand in such vessels, as the vegetable acids dissolve Cu readily. The black coating which collects on copper or brass kettles is the black oxyd of copper, CuO, and very poisonous. It dissolves readily in fats and oils. Such utensils should therefore be used only when perfectly bright, and then never with any fruits, sweetmeats, jellies, pickles, etc. Its solvent is NO₅. Its test is NH₃, forming in a solution a pale blue precipitate, which dissolves in an excess of the reagent.

SULPHATE OF COPPER (CuO.SO₃ + 5HO)—*blue vitriol*—is much used in dyeing, calico printing, and galvanic batteries.

L E A D.

Sym., Pb Equiv., 103.6 Spec. Gr., 11.44 Fusing Pt., 612°F.

Sources.—It is found almost pure in cubical crystals, but its most common ore is galena, a sulphuret

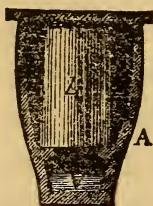
(PbS), which is reduced by roasting in a reverberatory furnace. The S burns and leaves the metal.

Properties.—It is malleable, but contracts as it solidifies, so it cannot be used for castings. It is poisonous, though not immediately, as bullets have been swallowed, and then thrown off without any harm except the fright. Its effects seem to accumulate in the system, and finally to manifest themselves in some disease. Persons who use lead, as painters and plumbers, after a time suffer with colics, paralysis, etc. It is much used for water-pipes, and is the most convenient of any metal for that purpose. Pure water passing through the pipe will not corrode the lead, but the O of the air it contains forms an oxyd of lead which dissolves in the HO. If there are any sulphates or carbonates in the HO, these will form a coating over the lead, and protect it from further corrosion ; and as carbonate of lime is common in all hard water, that is safe. If, when we examine a lead pipe that is in constant use, we find it covered with a white film, that is a good sign ; but if it is bright, there is cause for alarm. Still, however much may be said upon the danger, people will use lead pipes, and the following precautions should be observed : *Always let the water run long enough in the morning before using, to remove all which has remained in the water-pipes during the night, and after the HO has been drawn off for awhile, when it is let on again, leave the faucet open until the pipe is thoroughly washed.*

OXYD OF LEAD (PbO) is the well-known *litharge*, and is used in glass-making, in paints, and in glazing earthenware, as we have elsewhere described.

MINIUM, or *red-lead* (Pb_3O_4), is used for coloring sealing-wax red, and as a paint.

CARBONATE OF LEAD ($PbO \cdot CO_2$).—*White-Lead*.—This salt is made in large quantities in the following manner. Thousands of earthen pots fitted with

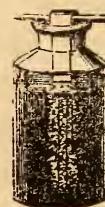


A—An earthen pot.
L—A coil of lead.
V—A solution of vinegar.

covers are filled with weak vinegar (acetic acid) and a small roll of lead, arranged in immense piles, and then covered with tan-bark. The acetic acid combines with the lead, but the CO_2 formed by the decomposing tan-bark creeps in under the cover, driving off the acetic acid, and forming carbonate of lead. The acetic acid, thus dispossessed, attacks another portion of the lead, but is robbed again; and so the process goes on, until at last all the lead is exhausted. White-lead is largely adulterated with sulphate of baryta—heavy spar. This can be easily detected by digesting (gently heating) a little in NO_5 , or even in strong vinegar, which will form a soluble nitrate or acetate of all the lead in the paint, while the baryta will settle to the bottom as a white precipitate.

ACETATE OF LEAD ($PbO \cdot A$)—*Sugar of Lead*.—This salt has a sweet, pleasant taste, and has been frequently taken by mistake, owing to its being in such common use. It is a virulent poison. The antidote is Epsom salts, which forms an insoluble sulphate

of lead. Water dissolves it readily. Ex.: If a piece of zinc, cut in small strips, be suspended in a bottle filled with a solution of this salt, the lead will be deposited upon it by voltaic action in beautiful metallic spangles, forming the "lead-tree."



The Lead-tree.

Test of Pb.—This is HS, which forms with the metal the black sulphuret of lead (PbS). A very comical illustration is as follows: Thicken a solution of PbO.Ä with a little gum-arabic, so as not to flow too readily from the pen, and then make the funniest drawing of which you can conceive. This, when dry, will be invisible. When it is to be used dampen the paper slightly on the wrong side, and then direct against it a jet of HS, and the picture will blacken into beauty.

ARSENIC.

Symbol, As....Equivalent, 75....Specific Gravity, 5.8.

Volatilez without fusion at 356° F.

This is a brittle, steel-gray metal, commonly sold when impure as *Cobalt*. If heated in the open air it gives off the odor of garlic, which is a test of As.

ARSENIOUS ACID (AsO₃).—This is the well-known "ratsbane," and is sometimes sold as simply "arsenic."

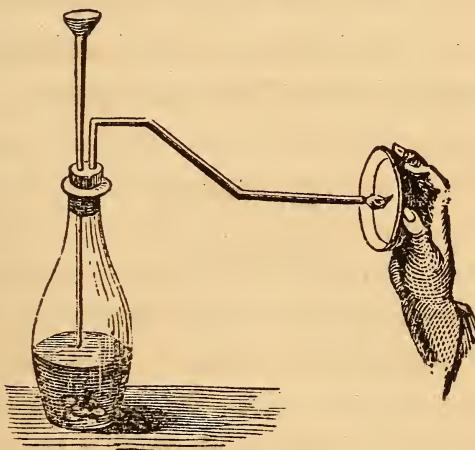
Preparation.—It is made in Silesia, by roasting arsenical iron ore at the bottom of a tower, above which is a series of rooms through which the vapors

ascend, and pass out through a chimney at the top. The As burns, forming AsO_3 , which collects as a white powder on the walls and floors of the chambers above. Its removal is a work of great danger. The workmen are entirely enveloped in a leathern dress and mask with glass eyes ; they breathe through a moistened sponge, thus filtering the air of the fine particles of arsenic floating through it. Yet, in spite of all these precautions, the workmen rarely live beyond forty.

Properties.—Arsenious acid (arsenic) is soluble in hot HO, and has a slightly sweetish taste. It is a powerful poison, doses of two or three grains being fatal, although an over-dose acts as an emetic. It is an antiseptic, and so in cases of poisoning frequently attracts attention by the perfect preservation of the body, even twenty or thirty years after the murder has been committed. The antidote is milk, whites of eggs, or s a s ds (the latter being good in almost any case of poisoning), taken *immediately*. The exact chemical antidote is the hydrated sequioxyd of iron, prepared by adding an alkali to a solution of copperas ($\text{FeO} \cdot \text{SO}_3$). The bulky precipitate soon reddens by the absorption of O from the air, and becomes the sesquioxyd. It must be perfectly fresh and moist to be of any value.

MARSH'S TEST.—There is no other poison which is so easily detected. Prepare a flask for the evolution of H. Ignite the jet of gas, and hold in the flame a cold porcelain dish. If the materials contain no

As, it will remain untarnished. Now pour in through the funnel-tube a few drops of a solution of As (made by dissolving a little AsO_3 in HCl), and the color of the flame will be seen to change almost instantly, and a copious "metallic mirror" of As will be deposited on the dish. The gas formed in this experiment—arsenuretted hydrogen—is very poisonous indeed, and the utmost care should be used to prevent its inhalation. In a case of poisoning, of



Marsh's Test.

course, the contents of the stomach would be substituted for the solution of As, and many other tests besides this would be employed. We can imagine with what care a chemist would conduct this test, and with what intense anxiety he would watch the porcelain dish as the flame played upon it, hesitating, and dreading the issue, as he felt the life of a fellow-being trembling on the result of his experiment.

Arsenic-eating.—It is said that the peasants in

portions of Hungary are accustomed to eat As, both fasting and as a seasoning to their food. A very minute portion will warm and stimulate and aid in climbing lofty mountains. The arsenic-eaters are described as plump and rosy, and it is said that the young people resort to it as a species of cosmetic to make them more attractive. They begin with small doses, which are gradually increased; but if the person should cease the practice at any time, all the symptoms of arsenic poisoning immediately appear. Horse-jockeys are said to feed arsenic to their horses to improve their flesh and speed.

CHROMIUM.

Symbol, Cr.

This element is commonly known as combined with O in chromic acid, CrO_3 . The ruby owes its beautiful red to this acid. Bichromate of potassa, $\text{KO} \cdot 2\text{CrO}_3$, is a red salt, much used in the laboratory, dyeing, etc. Example: If we mix a solution of this salt and one of sugar of lead, a yellow-colored precipitate will be formed, known as chrome yellow ($\text{PbO} \cdot \text{CrO}_3$), valued in painting and dyeing. Ex.: Moisten a piece of flannel in a solution of sugar of lead ($\text{PbO} \cdot \text{A}$), then in one of Glauber's Salts ($\text{NaO} \cdot \text{SO}_3$), to change the acetate of lead to a sulphate of lead, and lastly, in one of bichromate of potash, when the cloth will be found to be dyed a permanent yellow.

THE NOBLE METALS.

These are: Mercury, Silver, Gold, Platinum, Palladium, Iridium, Osmium, Ruthenium, Rhodium.

MERCURY.

Symbol, Hg....Equivalent, 100....Specific Gravity, 13.5.

Freezes at -39° F....Boils at 662° F.

Mercury is also called quicksilver, because it runs about as if it were alive, and was supposed by the alchemists to contain silver. It was known very anciently, and the mines of Spain were worked by the Romans.

Source.—Cinnabar, HgS , a brilliant red ore, called also “vermilion,” is the principal source of this metal. It is found native in Mexico in very small quantities, where the mines are said to have been discovered by a slave, who, in climbing a mountain, came to a very steep ascent. To aid him in surmounting this, he tried to draw himself up by a bush which grew in a crevice above. The shrub, however, giving way, was torn up by the roots, and a tiny stream, of what to him seemed liquid silver, trickled down upon him.

Properties.—Mercury emits a vapor at all temperatures above 40° F. Its solvent is NO_5 . It is the only element, except bromine, that is fluid at ordinary temperatures. It forms an amalgam—a union

of Hg and a metal—viz., gold or silver. We should therefore never touch a gold ring, for instance, to Hg, as it will cover it immediately with a thin film of this amalgam.

Uses.—Hg is extensively employed in the manufacture of thermometers, barometers, for silvering mirrors, and extracting the precious metals from their ores. The well-known *blue-pill* is Hg incorporated with chalk and flavored with liquorice. *Mercurial ointment*, “*anguintum*,” is Hg and lard well rubbed together. This is chiefly employed as an unguent for domestic use, and in very populous schools. Hg is extensively employed in medicine, as calomel, $Hg_2.Cl$, a subchloride of mercury. This can be distinguished from any other substance for which it is liable to be mistaken, especially corrosive sublimate, from the fact that it is insoluble in HO, and perfectly tasteless. The action of Hg on the human system is too well known to need description. “In its metallic state, Hg has been taken with impunity in quantities of a pound weight” (*Am. Cyc.*), but when finely divided, as in vapor or “*blue-pill*,” its effects are marked. It renders the patient extremely susceptible to colds, acts directly upon the liver, increasing the secretion of bile, and in over-doses produces “salivation.”

RED OXYD OF Hg, “red precipitate,” is interesting, as the substance from which Priestley discovered O gas.

CHLORIDE OF Hg ($Hg.Cl$), “corrosive sublimate,” is

well known to housekeepers. It is a heavy, white solid, soluble in HO, and with a burning metallic taste. It has powerful antiseptic properties, and is used to preserve specimens in natural history. It is a deadly poison, and its antidote is white of eggs, milk, etc.

Mirrors were anciently made of steel or silver, highly polished. They were very liable to rust and tarnish, and so a piece of sponge, sprinkled with pumice-stone, was suspended from the handle for rubbing the mirror before use. Seneca, in lamenting over the extravagance of his day among the old Romans, says: "Every young woman now-a-days must have a silver mirror." The process of silvering ordinary mirrors is as follows. Tinfoil is first spread evenly over the glass, and then the Hg is carefully poured over it. The two metals combine, forming a bright amalgam, which clings to the glass. The superfluous Hg is cautiously wiped or pressed off. When we look into a mirror we rarely realize what it has cost others to thus minister to our comfort. The workmen are short-lived. A paralysis sometimes attacks them within a few weeks after they enter the manufactory, and it is thought remarkable if a man escapes for a year or two. Its effects are similar to those we have just spoken of when treating of calomel; the patient dances instead of walks, he cannot direct the motion of his arms, nor in some cases even masticate his food.

IRIDIUM.

Symbol, Ir Equivalent, 99 Specific Gravity, 21.15.

This metal is named from Iris, the rainbow, because of the beautiful color of its salts in solution. It is the heaviest of the elements, being over 21 times as heavy as water. When combined with Osmium, it makes "irodosmine," well known as the points of gold pens.

PLATINUM.

Symbol, Pt Equivalent, 98.6 Specific Gravity, 21.5
Fusing Point, 4591° F.

Source.—Platinum is chiefly found in the Ural Mountains, where it occurs in alluvial deposits, in small, flattened grains.

Properties.—It resembles Ag in its appearance. It is the most ductile metal known, wire having been made from it so fine as to be invisible to the naked eye.* It is soluble in aqua-regia, but not in the simple acids. It does not oxydize in the air, is the most infusible of substances, and can be melted only

* Wollaston's Method, as it is called, consists in covering fine platinum wire with several times its weight of silver, and then drawing this through the plates used for drawing wire until the finest hole is reached, when the wire is placed in NO_5 , which dissolves the Ag and leaves the Pt intact. This, in the form of the finest wire known, may be found in the solution by means of a microscope. A single ounce of Pt, it is said, will make a wire that would reach from New York to New Orleans.

by the heat of the compound blow-pipe or voltaic battery. In the arts it is fused in the former manner. These properties fit it for use as crucibles in the laboratory, and for this purpose it is invaluable to the chemist.

G O L D .

Symbol, Au Equivalent, 196.4 Specific Gravity, 19.34.
Fusing Point, 2016° F.

Sources.—Gold is widely diffused. It occurs sometimes in cubes, in masses called nuggets, and is always native. It is found generally in small grains, or scales, scattered through the rocks. As these disintegrate by the action of the elements, the gold is gradually washed into the valleys below, and thence into the streams and rivers, where, owing to its specific gravity, it settles and collects in the mud and gravel of their beds. In this way we trace the origin of the extensive gold-plains of California.

Preparation.—As the metal is thus found native, the process is purely mechanical, and consists simply in washing out the dirt and gravel in wash-pans, rockers, etc., at the bottom of which the metal accumulates, the only requisites being these tools and an abundance of water. In the quartz-mills the rock is thrown into great troughs of water, in which, by heavy stamps, the ore is crushed to powder. As the thin liquid mud thus formed splashes up on either side, or is conducted from the stamping-mill, it runs

over broad metallic tables covered with mercury. This unites with the little particles of gold as they are washed along, and forms with them an *amalgam* (a compound of mercury and a metal). From this the gold is easily separated by distillation, and the mercury collected to be used again.

QUARTATION.—Gold is sometimes alloyed with silver. In that case the silver is dissolved out by NO_3 . There must be three parts of silver to one of gold, else the gold will protect all the silver from the action of the acid. If there is not so much, some is added.

Properties.—Pure ore is nearly as soft as lead. It is extremely malleable and ductile. Its solvent is aqua-regia. It does not oxydize at any temperature.

GOLD-LEAF.—The process of making gold-leaf is very simple. The metal is first rolled into thin ribbon, and then divided into pieces one inch square. These are placed, one by one, between leaves of gold-beaters' skin and hammered until they are beaten four inches square, when they are subdivided into four pieces, each one inch square. These are hammered as before, and the process repeated until the required thinness is obtained.

SILVER.

Symb., Ag....Equiv., 108....Spec. Gr., 10.5....Fusing Pt., 1873° F.

Sources.—Silver is found throughout the great West in a distracting variety of forms—most com-

monly, however, combined with S, as *black sulphuret*, AgS; with Cl, forming *horn-silver*, AgCl; with As, making *ruby-silver*, AgAs, and also associated with lead in ordinary galena.

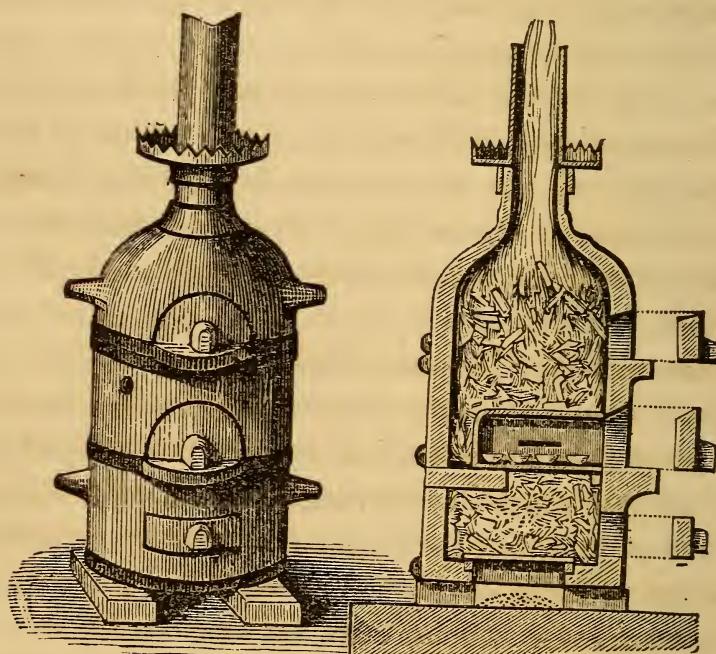
Preparation.—1st. The *sulphuret* is refined as follows. The ore is crushed into fine powder and then roasted with common salt. The Cl of the salt unites with the Ag, forming chloride of silver, AgCl. This is now put into a revolving cylinder with HO, Hg, and iron-scrap. The iron takes the Cl away from the silver, and the Hg catches it up, thus forming an amalgam of Hg and Ag. From this the silver is easily obtained, as in gold-washing. 2d. From *horn-silver*, AgCl, the process is like the latter part of that we have just described. 3d. From *lead* the silver can be profitably obtained even when there is not more than ten ounces in a ton. The alloy of the two metals is melted and then slowly cooled. Lead solidifies much sooner than silver, and by skimming out the crystals of Pb as fast as formed, they may be almost entirely separated.

Cupellation.—A cupel is a shallow vessel, made of bone-ashes. In this the silver, debased with lead and other impurities, is placed and exposed to a red heat, so as to melt the metals, while a current of hot air plays upon the surface. The lead oxydizes, is changed to litharge, PbO, and is absorbed by the porous cupel. The mass appears soiled and tarnished, but the refiner keeps his eye



A Cupel.

upon it as the process continues, watching eagerly, until at last there is a brilliant play of colors—he catches his own image in the perfect metallic mirror, and the little “button” of pure silver lies gleaming at the bottom.* This must now be immediately removed, or it will oxydize and waste.



Cupels in Furnace.

Properties.—Silver is the whitest of all the metals. It is malleable and ductile. It expands at the moment it solidifies, and, therefore, can be cast. It has a powerful attraction for sulphur, forming the black sulphuret of silver. The perspiration from our bodies contains more or less S, and this, as it

* Malachi, iii. 3.

passes through our pockets, fraternizes with any silver we may chance to have there. Silver spoons and door-knobs are tarnished by the minute quantity of HS present in the air. Those who have visited any sulphur springs know the propriety of carefully protecting their gold or silver watches, and of never carrying them to the hot baths. AgS is very easily dissolved by a little *dilute* ammonia (1 part of NH₃ to 10 of HO), which is therefore used for cleaning silver door-knobs. The solvent of Ag is NO₅. The test of silver in solution is HCl, which forms a cloudy precipitate of chloride of silver, AgCl. A solution of silver coin is blue, from the copper it contains.

NITRATE OF SILVER (AgO.NO₅).—It is sold in crystals, and also in sticks as *lunar caustic*. It is used as a cautery. It stains the skin and all organic matter black, owing to its decomposition by the light and the formation of oxyd of silver, AgO. A very pretty experiment, illustrating this, is performed by dropping into a test-tube of HO a few drops of nitrate of silver in solution, and then adding KO: a copious precipitate of AgO will fill the tube. At last add a little NH₃, and it will instantly dissolve the black oxyd, and leave the solution as clear and sparkling as spring-water. The stain from nitrate of silver may be removed by a solution of cyanide of potassium. Hair-dyes and indelible inks consist mainly of this salt of silver.

THE ALLOYS.

These are very numerous, and many of them possess properties so different from their elements that they almost seem like new metals. Their color and hardness are changed, and sometimes the melting point is below that of any one of the constituents.

Type Metal contains 3 parts lead to 1 of antimony.

Britannia consists of 100 parts tin, 8 antimony, 2 bismuth, and 2 of copper.

Brass is 4 parts of copper and 3 of zinc.

German Silver contains copper, zinc, and nickel—(brass whitened by nickel).

Soft Solder, used by tinsmiths, is made by melting lead and tin together, the orthodox proportion—half and half. Before putting on the solder, they moisten the surface of the metal with HCl, which dissolves the coating of the oxyd.

Hard Solder is composed of copper and zinc.

Fusible Metal melts at 203° , and spoons made of it will fuse in hot tea. It can be melted in a paper crucible over a candle. It consists of bismuth, lead, and tin. Yet the first metal melts at 476° , the second at 600° , and the third at 442° .

Bronze is 90 parts copper and 10 of tin.

Gold is soldered with an alloy of itself and silver; *Silver*, with itself and copper; *Copper*, with itself and zinc: the principle being that the metal of lower fusing point causes the other to melt more easily.

COIN.—The precious metals, when pure, are too soft for common use. They are therefore hardened by other metals. Gold coin consists of 9 parts gold and 1 of alloy. The alloy is composed of 9 parts of copper, whitened by one of silver, so as not to darken the gold coin. Silver coin is 9 parts silver and 1 of copper. The nickel cent is 88 parts copper and 12 of nickel. The object of the copper is to make the coin larger, as it is cheaper than nickel. The term carat, applied to the precious metals, means $\frac{1}{24}$ part. Therefore, gold 18 carats fine, contains $\frac{18}{24}$ of gold and $\frac{6}{24}$ of alloy.

SHOT is an alloy of about 1 part arsenic to 100 of lead. The manufacture is carried on in what are called "shot-towers," some of which are two hundred and fifty feet high. The alloy is melted at the top of the building, and poured through colanders. The metal, in falling so far, breaks up into drops, which take the "spheroidal form," harden, and are caught at the bottom in a well of water, which cools the shot and also prevents their being bruised in striking. The shot are dipped out, dried, and then assorted, by sifting in a revolving cylinder, which is set slightly inclined and is perforated with holes, increasing in size from the top to the bottom. The shot being poured in at the top, the small ones drop through first, next the larger, and so on, till the largest reach the very bottom. Each size is received in its own box. Shot are polished by being agitated for several hours with black-lead, in a rapidly

revolving wheel. The shot are finally tested by rolling them all down a series of inclined planes placed at a little distance from each other. The spherical shot will jump from one plane to the next, while the imperfect ones will fall short, and drop below; or sometimes, by rolling down a single inclined plane, the spherical ones will go to the bottom, while the imperfect ones roll off at the sides.

OREIDE—a beautiful alloy, resembling gold—is made at Waterbury, Connecticut. It is a French discovery. It consists of 100 parts copper, tin 17 parts, magnesia 6 parts, sal-ammoniac 3.6 parts, lime 1.8 parts, cream of tartar 9 parts. It can be beaten into leaves, cast, chased, rolled, and stamped like gold, while none but the most experienced judges can detect the difference.

ALUMINUM alloys with copper are becoming valuable, as Al is itself better known. They are elastic, malleable, and very light.

N.F.R. - +

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ORGANIC CHEMISTRY.

INTRODUCTION.

WE have thus far spoken of the various elements of matter. We have found "dead, mineral matter," as we commonly call it, all alive with desire and power. Each tiny atom has revealed to us a force that repelled it here, attracted it there, and held it to its place as with bands of iron. We have traced, through all the varied changes of matter, the workings of one law and one system, and have everywhere discovered our comfort and happiness to be the final end of creation. We have found the nicest cutting and planning, whereby each element appears fitted to its place in nature, as a skilful mechanic adapts one cog to another through a great series of machinery. No particle of matter seems left to itself, but, watched by the Eternal Eye and guided by the Eternal Hand, obeys immutable law. When Christ declared the very hairs of our head to be numbered, he intimated a chemical truth, which we can now know in full to be, that the very atoms of

which each hair is composed are all numbered by that same watchful Providence.

We have found the elements of the growth of our bodies, but still we cannot live upon them. We need phosphorus, but we cannot eat it; it would burn us to a coal. We need iron, but it would make a most unsavory diet. We need lime, but it would corrode our flesh. We need H, but it must be combined with O as HO to be of any value to us. If we were shut up in a room with all the elements of nature, we not only could not combine them so as to produce any of those organic substances necessary to our life and comfort, but we would actually die of starvation. We thus see that the mineral matter must be assimilated in some manner before we can use it to advantage. Here appears the object of the vegetable world. It turns *inorganic* matter into *organic*. The plant taking those elements which we need for our growth and for use in the arts and sciences, combines them into plant products, such as wood, starch, sugar, coal, etc.: we using these, live, grow, and develop into civilized man, fitted for all the grand achievements of life.

How strange it is that we are thus dependent upon plants! We know they decompose the poisonous CO₂, and give us our supply of the inspiring O, but that is only a part of our demands; they furnish us with all the grand staples of commerce, of luxury—all we eat, or drink, or wear. Each tiny leaf we see, each spire of grass is thus incessantly working

throughout the livelong day to meet our constant wants.

The object of ORGANIC CHEMISTRY is to treat of these plant-products and the various substances derived from them. Organic bodies differ from inorganic in several points.

1st. While inorganic bodies deal with 65 elements, organic are composed principally of only four, C, H, O, N—which are therefore called “ORGANOGENS”—and a very little mineral matter constituting the ash.

2d. While inorganic bodies consist of only a few atoms, and are therefore very simple in their construction (Ex.: HO, CO₂, KO), organic contain a large number, and are extremely complex. Ex.: Sugar = C₁₂H₂₂O₁₂; Oil of cedar = C₃₂H₃₆O₂; Fibrine = C₄₀₀H₃₁₀N₅₀O₁₂₀PS.

3d. While inorganic bodies are formed and remain fixed in one state under the influence of chemical affinity, organic grow rapidly, change constantly, and when life ceases, as rapidly decay, and are transformed into inorganic substances.

4th. Owing to their complex structure, and the presence in very many of the negative N, they form most unstable compounds. In this we see the reason of their rapid decay. The vital principle alone holds them together, frequently in opposition to the laws of chemical affinity; and the instant that is removed, the tendency is to seek new affinities and form new compounds.

NUMBER OF ORGANIC BODIES.—This is almost endless, and yet is constantly increasing. The labor of modern chemists is largely devoted to this subject, and the field opens and broadens with every discovery. The methods of classification are unsettled, and new and conflicting theories yet contend on this border-ground of chemical knowledge. Various organic bodies are now formed artificially by the skill of the chemist, and many others are broken up into simpler forms. Ex.: Alcohol = water and carburetted hydrogen.

ISOMERISM.—Isomeric compounds are those that consist of the same elements in the same proportion. Ex.: Heavy carburetted hydrogen, petroleum, oil of roses, and caoutchouc, consist alike of C_4H_4 . So that the fragrant odor of a rose, and that which comes from a petroleum lamp, contain precisely the same elements. Isomerism is supposed to be caused by a different grouping of the atoms about each other, as the same pieces upon a checker-board may be differently arranged.

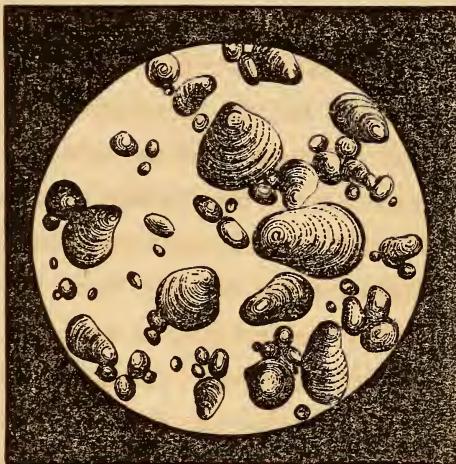
ALLOTROPISM.—Not only may the same elements be thus differently grouped, and produce different compounds, as p-l-e-a may spell also l-e-a-p, or p-e-a-l, or p-a-l-e, but also the individual elements are susceptible of allotropic states; as, for instance, the C in a compound may be in any one of its three allotrophic forms. These two principles of isomerism and allotropism run through organic chemistry, and

readily account for the inexhaustible variety of its compounds.*

STARCH ($C_{12}H_{10}O_{10}$).

Source.—Plants accumulate it in their roots—Ex., Carrot, turnip : in subterranean stems—Ex., Potatoes, of which it forms 20 per cent.: in the base of leaves—Ex., Onion : in the seed—Ex., Corn, of which it forms 80 per cent: in the embryo—Ex., Bean, pea. In all these it is stored up for the future growth of the plant or the seed. It is kept in its starch form (lest it dissolve in the first rain), and then turned to sugar only when and as the plant needs it in growing. The accompanying figures show the form of the grain of starch in a potato, as seen under the microscope, each vegetable having its peculiar shape, so that in this way any adulteration is easily detected.

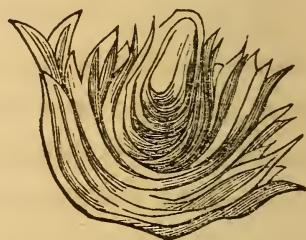
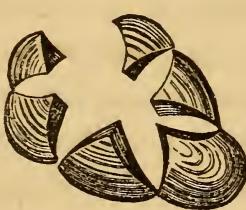
Preparation.—It is made from wheat, corn, potatoes. The process is essentially the same in all. The potato, for example, is ground to a pulp, and



Starch Grain.

* See ORGANIC CHEMISTRY, in Appendix.

then washed with cold water. The starch settles from this milky mass as a fine white precipitate.



Properties.—It is insoluble in cold water. If heated it absorbs water, swells, and the starch granules burst, forming a jelly-like liquid, used for what is known as *starching*. The swelling of rice, beans, etc., when cooked, is owing to this property. By heat, starch undergoes a peculiar change into a substance known as dextrine, or British gum, used for making envelopes, wall-paper, "fig-paste," and for stiffening chintzes. The test of starch is iodine, which forms in solution a beautiful blue iodide of starch. Sago is the starch from the pith of the palm-tree; tapioca and arrow-root are made from the roots of South American marshy plants. Very many of the farinaceous preparations sold for the sick and invalid, under high-sounding names, are simply wheat or corn starch, put up in fancy papers and gilt lettering.

GUM ($C_{12}H_{10}O_{10}$).—This includes a variety of substances which exude from the bark of trees. Ex.: Cherry, plum. Gum-arabic is derived from an *Aca-cia* tree.

PECTIC ACID, OR PECTINE.—This is a variety of gum existing in certain fruits, as the currant, apple, etc., which forms the vegetable jelly so much used as a sweetmeat. In the fully ripened fruit, this turns to sugar, and hence, as every housewife knows, a jelly cannot be made from the fruit except at a certain stage in the ripening process.

CELLULOSE, LIGNINE, ETC. ($C_{12}H_{10}O_{10}$).—Woody fibre is found in various modifications—in the heart of a tree, in shells of nuts, and stones of fruits. Its cells, filled with lignin, are hard and compact; in the sap-wood, its cells, open and full only of sap, are soft and porous; in elder-pith and cork, they are light; in flax and cotton, pliable; in the bran of wheat and corn, very digestible. It composes the cells of all plants, giving them strength and firmness, and is found even in delicate fruits, holding their luscious juices.

Secretion.—All vegetation consists of these simple cells. They seem alike to the eye, yet they have a wonderful power of secretion. The cell of the sugar-maple converts the sap into sugar—the milk-weed, into a milky juice—the caoutchouc, into rubber; the pie-plant manufactures oxalic acid, and the rose-petal the most delicate of perfumes. Then again they are true to themselves. There seems to be a law of God stamped on each cell, so that when we cut a tiny bud from a tree and graft it into another, it remains consistent with itself. It develops into a limb, and years pass by—the few single cells become a myriad, yet

they have changed not. The sap flows upward in the tree; but at a certain point—a hidden threshold which no human eye can discern—it comes under a new and strange influence. It is here transformed, and produces fruit and flowers, in accordance with this new law. Somehow quince-juice is made into pears, locust-juice blooms out into fragrant acacias, while sweet apples and sour apples hang “cheek-by-jowl” on the same limb.

Uses.—These are wonderfully various. Woody fibre is woven into cloth, built into houses, twisted into rope, twine, and thread, cut into fuel, carved into furniture. We eat it, wear it, walk on it, write on it, sit on it, print on it, pack our clothes in it, sleep in it, ride in it, and burn it.

Curious Discovery.—It has lately been found that, by feeding the roots of a tree with some coloring matter, the wood of the trunk may be stained to imitate any color desired. In this way, common pine or maple takes the appearance of the rarest wood—mahogany, rosewood, etc.

PAPER is made from rags of all kinds, straw, or indeed almost any substance containing cellular tissue. The finest writing-paper is manufactured from the best of linen rags, brought from Italy. The rags are first shredded upon scythe blades—*i. e.*, the seams are ripped open, buttons cut off, and the dust shaken out. 2d. They are steamed in a solution of chloride of lime for ten or twelve hours until they are *thoroughly bleached*. 3d. They are received

by a machine that alternately lacerates them by a cylinder set with razor-like blades, and washes them with pure cold water for six hours, or until they are reduced to a mass resembling rice and milk. 4th. This mass receives a delicate blue tint from *smalt*—powdered glass colored with oxyd of cobalt. 5th. It is diluted with HO to the consistency of city milk, and sifted, to strain out the waxed ends and knots of thread that cause the provoking little lumps that catch our pen when we write rapidly on poor paper. 6th. It flows over an endless or circular belt of wire-gauze, about 30 feet long, beneath which is a steam air-pump that greedily sucks down the water from the pulp, as it slowly passes along, gaining consistency and firmness until it comes to a part of the belt called the “dandy-roll,” consisting of a cylinder, on the surface of which are wires arranged in parallel rows, or fancy letters, which print upon the moist paper any design—constituting what are termed “laid,” “wire-wove,” or “water-marks.” 7th. The paper, very soft and moist as yet, but still quite paperish in its appearance, passes between rollers that squeeze out the water; then between others which are hot and dry it, which bring it, 8th, to a vat of sizing, composed of the same material as the gelatin of calves-foot jelly, into which it plunges, and at the opposite side emerges only to come between other rollers that squeeze and dry it—at the end of which it passes under a cylinder, set with knives, that clip the roll into sheets of any desired size.

PARCHMENT is prepared by plunging unsized paper for a few seconds in SO_3 and HO , then washing off the acid. This strengthens it in some unknown way, and entirely changes its appearance and character, so that a narrow strip will support a hundred pound weight, though before a small fraction of that would have torn it instantly.

LINEN.—This is made from the inner bark of flax. The plant is first *pulled* from the ground to preserve the entire length of the stalk; next “rotted” by exposure to air and moisture, when the decayed outer bark is removed by “breaking;” then, by “hatcheling,” the long fine fibres are divided into shreds, and laid parallel, while the tangled ones are separated as “tow.” It is then bleached on the grass, which renders the gray coloring-matter soluble by boiling in lye. The whitened flax is lastly woven into cloth.

COTTON consists of the beautiful hollow white hairs arranged around the seed of the cotton-plant. As it is always pure and white—except Nankin cotton, which is yellow—it would require no bleaching did it not become soiled in the process of spinning, etc.

GUN-COTTON is prepared by dipping cellular tissue—cotton, sawdust, printing-paper, etc.—in strong NO_5 . It is then carefully washed and dried. It is not materially changed in appearance, although it has less strength. It sometimes takes fire at the boiling-point of HO . It explodes with much greater violence and suddenness than gunpowder, and for that reason is more liable to burst the gun.

COLLODION is a solution of gun-cotton in sulphuric ether and alcohol. It forms a syrupy liquid, which is an excellent substitute for court-plaster.

EREMACAUISIS.—When wood decays slowly in the open air, the H passes off first, the proportion of C increases, the color darkens, and a black carbonaceous mass like muck remains, called humus. This is of great value to the soil, as its pores absorb NH₃, and by its decay furnishes that and CO₂ to the growing plant. When the supply of humus is exhausted from the soil, we restore it by adding straw, etc., and by ploughing under green crops.

DESTRUCTIVE DISTILLATION OF WOOD.—When wood is heated to a high temperature, with no O present, or an imperfect supply, as in our stoves, it is decomposed, the charcoal remains, while the volatile constituents pass over in the form of illuminating gas, HO, pyroligneous acid, and wood-tar. This latter is a thick liquid used for calking and tarring ships: on distillation it yields benzole, creosote, and paraffine.

PYROLIGNEOUS ACID (*wood-vinegar*) is obtained by the distillation of beech-wood. It contains much creosote and acetic acid. On account of the former property it is used for curing hams in commerce, and on account of the latter, for making salts called acetates.

CREOSOTE (flesh preserver) is a colorless liquid with a flavor of burnt wood. It is poisonous when taken in any quantity. It is a powerful antiseptic, and a mixture of 1 part creosote in 100 parts HO will, in a

few hours, give a ham a delicate smoky flavor and render it incapable of putrefaction. Creosote imparts to smoke its characteristic odor, and renders it so irritating to the eyes, and also gives to it the power of curing hams, dried beef, etc.

TAR is made, like charcoal, by burning heaps of wood under a covering of earth which excludes the air: an imperfect combustion ensues, the resinous matter exudes, and, trickling down to the hollow bottom, collects and runs into a reservoir. On the extensive pine-barrens of North Carolina the tar of commerce is principally produced.

TURPENTINE.—When tar is distilled it separates into pitch, which remains, and oil of turpentine, which passes off. The latter, redistilled, forms the rectified “spirits of turpentine.” The residuum of the distillation is called “rosin.”

COAL-TAR is formed, as we have seen, in the process of making illuminating gas. This was formerly thought valueless, but is now used for a variety of purposes. As a cement for roofs, walks, and pavements, for oiling machinery, and preserving wood from decay, it is invaluable. On distillation it yields the following, among other products: 1st, *benzole* (benzine), used as a solvent for gutta-percha, caoutchouc, wax, and for removing grease-spots. This, by distilling with NO_5 , gives *nitro-benzole*, which so nearly resembles the oil of bitter almonds that it is used for it in perfumery, confectionery, etc. By heating it with acetic acid and iron-slings

analine is commonly prepared. 2d, *Paraffine*, a hard, white, tasteless solid, like spermaceti. It forms beautiful candles, which look and burn like the finest of wax. 3d, *Analine*, from which some of the most exquisite colors of every shade are produced. Example: Mauve, magenta. When first prepared, analine was worth more than gold, and is even now expensive; but its dyeing properties are very intense. (Who but a chemist would have searched for such brilliant colors in coal-tar!) 4th, *Carbolic acid*, which, by heating with NO_3 , dyes a rich yellow; it is also used as a disinfectant. The production of dye-stuffs from coal-tar formed an era in organic chemistry, and revolutionized the whole art of dyeing and calico-printing.

PETROLEUM is doubtless the product of the distillation of organic matter beneath the surface of the earth. It is not always connected with coal, as it is often found outside the coal-measures, as in Northwestern Pennsylvania and New York. The distillation must have taken place at a much greater depth than that at which the oil is now found, as it would naturally rise through the fissures of the rock and gather in the cavities above. Sometimes the oil has collected on the surface of subterranean pools of salt-water, so that after a time the oil is exhausted, and salt-water only is pumped up; or if the well strikes the lower part of the cavity, the water will first be pumped and afterward the oil. The crude oil from the well is purified by distillation. That

which passes over at the lowest temperature is called *naphtha*: as the heat is increased, there passes over next the *kerosene oil* for illumination, and lastly the *lubricating oil*. The kerosene is deodorized and decolorized by the use of sugar of lead, SO_3 , KO, and other chemicals, which are stirred in the oil, after which it is redistilled.

Bitumen or *Asphaltum*.—Petroleum (*petra*, a rock, and *oleum*, oil) and naphtha, flowing from the ground, have formed beds of bitumen in various parts of the world. This change is caused by a gradual oxydation and hardening, as turpentine changes to rosin. On the island of Trinidad is a lake called Tar Lake. It is nearly three miles in circumference. Below it is a bed of coal, from which the oil is doubtless distilled. The bitumen from the lake is used for the same purposes as pitch, which it closely resembles. Near the shore it is hard and compact, except in hot weather, when it becomes sticky. At the centre it is soft, and fresh bitumen boils up to the surface. Asphaltum is found in immense quantities in California and in Canada. It is a natural cement for laying stone or brick. It was used in building the walls of Babylon, for which purpose it was gathered from the fountain of Is on the banks of the Euphrates. It was a prominent ingredient in the “Greek Fire,” so much used by the nations of Eastern Europe in their naval wars, even as late as the fourteenth century. This consisted of bitumen, sulphur, and pitch, which was

thrown through long copper tubes, from hideous figures erected on the prow of the vessel. It was said to be inextinguishable except by wine or vinegar. Bitumen is used in making the famous promenades of the Boulevards in Paris.

CANE-SUGAR ($C_{12}H_{11}O_{11}$)* is obtained from the sap of the sugar-maple, sugar-cane, sorghum, and the juice of the beet. In making it from the sugar-cane, the canes are crushed between iron cylinders, thus expressing the juice. As it sours very soon, from the heat of the climate in which it grows, a little lime is added to neutralize the acid, and it is then evaporated to a thick jelly, and set aside to cool. The sugar crystallizes readily, forming *brown sugar*, which is put in perforated casks to drain. The drainings constitute molasses.

Refining of Sugar.—Brown sugar is refined by dissolving it in HO, then adding albumen (whites of eggs, blood, etc.), which, on heating, coagulates and settles to the bottom with the coarser impurities. The solution is then filtered through animal charcoal,

* Ex.: A very brilliant illustration of the presence of C in $C_{12}H_{11}O_{11}$ is obtained by putting on a clean white plate a mixture of finely pulverized white sugar and $KO.ClO_5$. Upon adding a few drops of SO_3 , a vivid combustion will ensue. By mixing also a few iron and steel filings, and performing the experiment in a dark room, or out of doors at night, fiery rosettes will flash through a rose-colored flame, and produce a fine effect. The contrast between the white plate and mixture and the dense black carbonaceous compound covering the adjacent floor, is very striking to the eye.

and finally evaporated in vacuum-pans, from which the air is exhausted, so that the sugar boils at 140°F., and all danger of burning is avoided. From this the sugar crystallizes, and the white sugar is set aside to drain. The drainings constitute "syrup," "sugar-house molasses," etc.

ROCK CANDY is formed by suspending threads in a strong solution of sugar. It crystallizes upon the rough surface in large six-sided prisms.

CONFECTIONERY is commonly supposed to be made from sugar. Alba terra (white earth) is now largely imported from Ireland for use in lozenges, candy drops, etc., enough sugar only to flavor being added. We can and should test all the candy we purchase by putting a small piece in a glass of water. Whatever settles to the bottom cannot be sugar, but is a vile adulteration. Candies also are often colored by the direst poisons, so that prudence would forbid the use of any colored candy whatsoever. The grocer or dealer is as liable to be mistaken or ignorant in regard to the purity of his candies as we ourselves. Licorice drops are frequently only the poorest brown sugar, terra alba, and a flavoring of licorice to make the unwholesome mixture palatable. Gum-drops are generally made, not from gum-arabic, but the best kinds are composed of a species of glue manufactured out of hoofs, parings of hides, offal, etc., from the slaughter-houses. And yet, however repugnant it may appear, this glue is perfectly clean and wholesome. Many kinds of gum-drops and

lozenges are made from dextrine, terra alba, plaster of Paris, a little sugar, and some flavoring extract.

CAROMEL, familiarly called *burnt sugar*, is formed whenever sugar is heated above 400° F., when it parts with four equivalents of water, leaving the C in excess, as when sweetmeats boil over on the stove. It is used extensively in coloring liquors.

GRAPE-SUGAR ($C_{12}H_{14}O_{14}$).—This variety of sugar includes the sugar of grapes, figs, all common fruits, honey, etc., in which forms we are familiar with it. It has much less sweetness than cane-sugar.

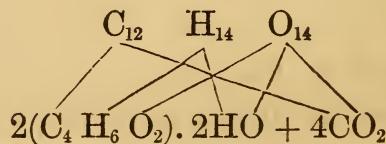
SUGAR FROM STARCH OR WOOD.—Starch and woody fibre differ only from grape-sugar by four atoms of HO. By slowly heating with SO_3 , diluted largely with HO, common sawdust, paper, and old rags even, can be converted into sugar. Indeed, Professor Pepper speaks of eating a fine quality of grape-sugar made out of an old flannel shirt he had outgrown. The weight of sugar exceeds that of the woody fibre used by the additional four elements of HO. This change takes place in the plant. The green fruit contains starch, which, as the fruit ripens, is turned into grape-sugar. If it over-ripens, the sweetness is lost, as the sugar is reabsorbed by the plant and converted into woody fibre again. In the sap of the sugar-maple tree there is much grape-sugar, but as the leaves start they hasten to stop this pilfering of their sweet juices by turning it into cellular tissue—into the wood of the tree. The farmer knows that if he does not cut his grass at the

proper time it will undergo this change, and become tough and tasteless and of little value to him. The starch in potatoes is turned to sugar by freezing, and so frozen potatoes taste sweet.

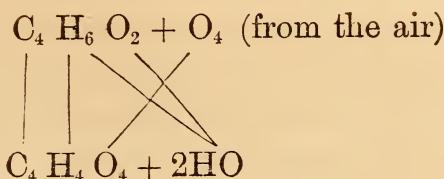
FERMENTATION.

If a solution of starch or sugar be exposed to the air it will undergo no change, but if there be added a little ferment or yeast, flour-paste, or any albuminous substance (*i. e.*, one containing N), in a decomposing state, it will immediately commence breaking up into new compounds. There are two stages in this chemical change.

1st. ALCOHOLIC FERMENTATION.—In this, the sugar is resolved into alcohol, water, and carbonic acid. The two former remain in the liquid, while the latter escapes in little bubbles of gas. The reaction is as follows:



2d. ACETOUS FERMENTATION.—The second stage succeeds the first immediately, if not checked, and by absorbing oxygen from the air, the *alcohol is broken up into acetic acid and water.*



YEAST is composed of microscopic plants formed during the process of fermentation. So minute are they, that it is said a cubic inch contains 1,200,000,000 of them. In the malting of barley they spring up in great abundance, making common brewer's yeast. The yeast-cakes of the kitchen are formed by exposing moistened Indian meal, containing a ferment, to a moderate temperature until the gluten or albuminous matter of the cake has undergone this alcoholic fermentation. It is then laid aside for use. A heat of 212° , or a cold of 10° , will kill the yeast plant and destroy its efficiency as a ferment.

MALT.—In making malt, the barley is thoroughly moistened, and then spread on the floor of a dark room (malting-room), to heat and sprout. Here a curious change ensues, identical with that which takes place in every planted seed. Each one contains starch and a nitrogenous substance called *gluten*. The tiny plant not being able to support itself in the beginning, has here a little patrimony to start with in life, but, as the starch is insoluble in its sap, it must first be changed to sugar. We see, therefore, the need of a ferment; but it would not answer to store up in the seed an active ferment, as that might cause a change before the plant was ready to

grow, and thus the plant's capital be wasted. The gluten is therefore a *latent* ferment, as it were. As soon as the seed is planted it absorbs moisture from the ground, is turned into *diastase*—an *active* ferment—the starch is converted into sugar, dissolved, and immediately applied to the uses of the growing plant. This change takes place in the *malting-room*. The barley sprouts, and a part of its starch is turned to sugar, so that it tastes quite sweet. If this germination were allowed to proceed, the little barley sprout would turn this sugar into woody fibre. To prevent this the grain is heated in a kiln until the germ is destroyed. Barley in this condition is called *malt*, and is then transported to the breweries.

BREWING BEER.—The malt is crushed and digested in water, to convert all the remaining starch into sugar. Having been boiled, to clarify it, hops and yeast are added, and fermentation immediately commences. Bubbles of gas rise to the top with a low hissing sound, yeast gathers into a foamy cream that comes to the surface of the tub, and the alcohol gradually accumulates in the liquid. It is now drawn off into tight casks, where it undergoes a second fermentation; the flavor of the beer ripens, and the CO₂ collecting, gives to the liquor, when drawn, its sparkling, foamy appearance.

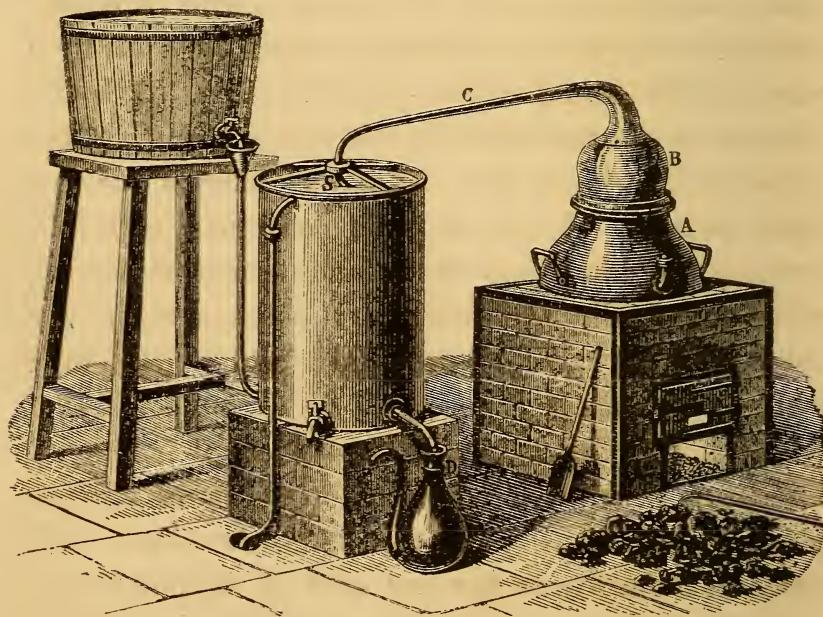
LAGER BEER (*Lagen*, to lie) is so called because it is allowed to lie for months in a cool cellar, where it ripens very gradually. It is also fermented much more slowly and perfectly than ale or porter.

WINES are commonly made from the juice of the grape. The juice, or *must*, as it is called, is placed in vats in the cellar, where the low temperature produces a very slow fermentation. Before the sugar is all converted into CO₂ and alcohol, the wine is bottled. The undecomposed sugar gives the flavor to sweet wines, while the CO₂, formed afterward and dissolved in the liquid, produces the effervescence of sparkling wines. The sugar keeps the wine and rather improves its body for even a couple of centuries. The bouquet, or flavor of wines, is given by a very volatile liquid called *œnanthic ether*. It is developed in its perfection by age alone, and gives the value to old wines. The acidity of wine is due to a small quantity of tartaric acid combined with KO, forming the bitartrate of potash (cream of tartar), which gradually separates and collects upon the sides and bottoms of the casks and bottles in a white incrustation.

ALCOHOL IN BEER AND WINE.—Alcohol is the intoxicating principle alike of all varieties of liquors, ale, beer, wine, cider, and the domestic wines. Ale contains from five to ten per cent. of alcohol; wine varies from five per cent. in the light Champagne to twenty-five per cent. in the strong Port, Madeira, or Sherry.

ARDENT SPIRITS.—When any fermented liquor is distilled, the alcohol passes over at a temperature of 173°, together with some water and fragrant substances which are condensed. In this way

brandy is made from wine ; rum from fermented molasses ; whiskey from fermented corn, rye, or potatoes ; gin from fermented barley and rye, afterward redistilled with juniper-berries ; alcohol alone from whiskey. The percentage of alcohol in these spirituous liquors varies from fifty to seventy per cent. The accompanying cut represents an apparatus used for this distillation. A is the boiler, B the



A Still.

dome, C a tube passing into S, the condenser, where it is twisted into a spiral form called the worm, in which the vapor from the boiler is condensed, and drops out at D.

ALCOHOL (C_2H_5OH) is prepared by distilling whiskey,

and is sometimes called spirits of wine. It boils at 173° , and has never been frozen even at -166°F . It contains, when purest, ten per cent. of HO, which can be separated by adding some substance like CaCl, which has a strong affinity for HO. It is then called *anhydrous* or absolute alcohol. When $\text{C}_2\text{H}_6\text{O}_2$ is exposed to the air the spirit evaporates, while it also attracts moisture from the atmosphere. The chemist discovers this when he neglects to put the extinguisher on his alcohol-lamp and finds that he cannot relight it without moistening the wick with fresh alcohol. It burns without smoke and with intense heat, owing to the abundance of H and deficiency of C, and is therefore of great value in the arts. It is also of incalculable importance as a solvent in forming tinctures of many substances—roots, resins, fragrant oils, etc.

Effects of Alcohol.—When pure it is a deadly poison. When diluted, as in the ordinary liquors, it is stimulative and intoxicating. Its influence is on the brain and nervous system;—deadening the natural affections, dulling the intellectual operations and moral instincts; seeming to pervert and destroy all that is pure and holy in man, while it robs him of his highest attribute—reason. It is a blight upon a family, a curse to society, and the bane of our civilization. In a word, alcohol makes drunkards, and a drunkard is the saddest, most shocking sight this world affords.

ETHER ($\text{C}_2\text{H}_5\text{O}$).—Sulphuric ether is formed by the

H_2SO_4 H_2SO_3

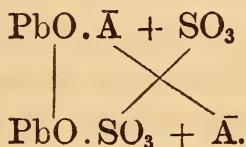
distillation of $C_4H_6O_2$ with SO_3 . The SO_3 simply takes an atom of HO out of the alcohol. It has a fragrant odor, boils at 96° , and burns with more light and smoke but less heat than alcohol. By the action of the other acids on $C_4H_6O_2$ varieties of ether are produced—viz., nitric ether, carbonic ether, etc.

AMYLIC ALCOHOL (*fusel oil*) is one of a large class of substances similar to alcohol, and thus called “the alcohols.” It is formed in distilling whiskey from potatoes. It is present in common $C_4H_6O_2$, giving that slightly unpleasant odor when it evaporates from the hand. It is extremely poisonous, and though contained in liquors in very small quantities, is said to greatly increase their destructive and intoxicating properties. It is of interest, mainly because by distilling it with different acids, various products are obtained, having the most delicate flavor and odor. Pear, apple, orange, and many other “flavoring essences” are thus prepared. Though made from the poisonous fusel oil, they are perfectly innocuous.

CHLOROFORM (C_2HCl) is made by distilling $C_4H_6O_2$ with chloride of lime. It is colorless, volatile, of a sweet taste, and should be free from any unpleasant odor when evaporated on the hand. It is mainly used as an anæsthetic. The value of ether and chloroform in alleviating pain, is beyond estimate. On the battle-field, in hospitals, everywhere, our soldiers have sunk into pleasant slumber, while the

most painful surgical operations have been performed.

ACETIC ACID ($C_4H_4O_4$, \bar{A}).—When any fermenting substance has reached the first stage—the *alcoholic* fermentation—if the process be not stopped, it passes on to the second—the *acetous* fermentation, forming acetic acid and water. This acid is well known as common vinegar, of which it forms about five per cent. The acid of commerce is prepared by the action of SO_3 on acetate of lead (sugar of lead) $PbO \cdot \bar{A}$. The reaction is—



CIDER VINEGAR.—Cider contains some nitrogenous matter, which acts as a ferment, and the vinegar of the apple is broken up into alcohol and carbonic acid. This makes what is called “old cider.” By exposure to the air and heat, which always hastens chemical change, the alcohol passes on to the second stage, and the acetic acid formed produces the sour taste of the vinegar. “Mother,” in vinegar, is a plant produced by the decomposition of the nitrogenous matter. It acts as a ferment, and frequently generates a nation of infusoria—vinegar eels. Acetic acid is a solvent of albumen, gelatin, fibrin, etc. Hence it takes from meat, eggs, oysters, etc., pickled in it, their most strengthening constituents. For the

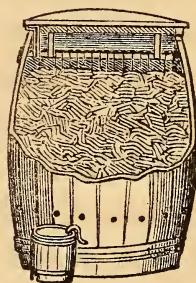
same reason, vinegar is a valuable assistant in digesting such food. It allays thirst, and was anciently carried by the Roman soldiers in a little flask for that purpose. In the case of young ladies who use it (as well as slate-pencils), to relieve corpulency, it produces delicacy and finally consumption. Any sugar added to vinegar quickly passes to the second stage of fermentation, and increases its strength. Indeed, vinegar is sometimes made entirely from tea-leaves, which act as the ferment, and sweetened water. Vinegars of commerce are frequently sharpened by the addition of SO_3 and pungent spices. We can easily detect these by evaporating a half-gill in a saucer, placed over boiling water. As it boils down, add a little honey. If the grape-sugar it contains turns black, it is proof of the presence of SO_3 . As the last of the liquid evaporates, the odor of cayenne pepper, etc. (if there be any), can be readily distinguished.

A new Method.—The following method has lately been adopted in England. A thin liquid made from malt and HO is allowed to pass into the first stage of fermentation. A large vat is filled with short pieces of wicker-work, which are kept wet with an old vinegar wash until the surface of the wicker-work is covered with young vinegar-plants; these grow until they fill all the empty space. The weak alcoholic liquid is now permitted to trickle down through this vat full of *mother*, while at the same time the heat of the chemical change causes an upward cur-

rent of air through holes at the bottom of the vat. Before the liquid reaches the faucet below, it presses into the second stage of fermentation.

QUICK VINEGAR PROCESS.—Vinegar is now made on a large scale by filtering a mixture of alcohol and yeast through a cask filled with beech shavings soaked in vinegar. As the fermenting alcohol slowly trickles down, it comes in close contact with the air, absorbing O so rapidly that sometimes before it reaches the bottom it becomes entirely converted into vinegar.

PRESERVES frequently *work*, as it is called, and then *sour*. The bubbles of gas which rise to the surface indicate the first or alcoholic stage of fermentation. If neglected, this soon passes to the second. It may be checked by scalding, which destroys the ferment.



VEGETABLE ACIDS.

There are many of these found native in plants—most generally, however, combined with some base.

OXALIC ACID ($C_4H_6; \bar{O}$) is familiar in the sour taste of pie-plant, sorrel, etc., in which it is combined with KO, which largely neutralizes its acid properties. It is prepared by the action of NO_5 on sugar.* \bar{O}

* Oxalic acid is also made on a large scale from sawdust, soda, and potash. The woody fibre is resolved into oxalic acid,

is a potent poison. Its antidote is a drink of powdered magnesia, or chalk, stirred in HO. It is a test of lime, forming a delicate white precipitate of oxalate of lime. Its solution is much used to remove ink stains, and it is sold for this purpose under the deceptive and dangerous name of "salts of lemon." The acid unites with the iron of the ink, and the oxalate of iron thus made is easily dissolved in HO. It should be thus washed out immediately, as it will corrode the cloth. The crystals of O , it should be noticed, very much resemble those of Epsom salts, and many serious mistakes have occurred in consequence.

TARTARIC ACID ($\text{C}_8\text{H}_4\text{O}_{10}$, \bar{T}) exists in many fruits, principally in the grape, combined with KO as $\text{KO} \cdot 2\bar{T}$, the bitartrate of potassa. This settles during the making of wine, as we have seen, and when purified is called *cream of tartar*. From this T is made. It forms large, colorless crystals, of a pleasant acid taste, which are permanent in the air. Its solution gradually becomes mouldy and turns into \bar{A} . *Rochelle salt* is a double tartrate of potassa and soda; it is a purgative, and is much used in Rochelle, or *Seidlitz*, powders. These are combined in a blue and a white paper. The former holds 120 grains of Rochelle salt, and 40 grains of bicarbonate of soda;

which combines with the bases, forming oxalates of soda and potash. From these the acid is readily obtained. Sawdust will yield more than half its weight of crystals of this salt.

the latter 35 grains of tartaric acid. These are dissolved in separate goblets. The one containing the acid is emptied into the other, when the CO₂ is set free, producing a violent effervescence and disguising the taste of the medicine. *Tartar emetic* is a double tartrate of potassa and antimony.

CITRIC ACID (*citrus*, lemon) is the sour principle of the citron, orange, lemon, cranberry, etc. It is combined with lime in the onion.

MALIC ACID (*malus*, an apple) is found in the apple, peach, pear, plum, cherry, etc.

TANNIC ACID (*tannin*) is found in the leaves and bark of many trees. Example : Oak, hemlock, sumach. Nutgalls is an excrescence which forms on oak-trees when punctured by insects for the purpose of laying their eggs. Tea and coffee contain from 8 to 10 per cent. of tannin. It has a bitter, astrigent, puckering taste, is soluble in water, and hardens all albuminous substances, such as gelatine, etc.

TANNING.—After the hair has been removed from the skins by milk of lime, they are soaked for days, the best kinds for months, in vats full of water and ground oak or hemlock bark (tan-bark). The tannic acid of the bark is dissolved, and entering the pores of the skin, unites with the gelatin, forming a hard insoluble compound which is the basis of leather. Leather is blackened by washing the hide on one side with a solution of copperas (FeO.SO₃). The tannic acid unites with the iron, forming a tannate

of iron—a real ink. In the same way drops of tea on a knife-blade stain it black.

INK is made by adding a solution of nutgalls to one of copperas. The tannate of iron thus formed has a pale blue-black color, as in the best writing-inks. By exposure to the air the iron absorbs more O, and becomes changed from the protoxide to the sesquioxide, thus darkening in color until it is a deep black. Gum-arabic is added to the ink to thicken it and regulate its flow from the pen. Cloves or corrosive sublimate are used to prevent mouldiness. Steel pens are corroded by the free SO₃ contained in the ink, but gold pens are not affected by it.

Experiment.—The following is an instructive experiment, illustrating the manner of making ink, of removing stains with oxalic acid, and also the relative strength of the acids and alkalies. Take a large test-tube, and add the following reagents in solution *cautiously, drop by drop*, watching the result and explaining the reactions :

Sulphate of iron (<i>copperas</i>)	FeO ₄ SO ₃
Tannic acid (<i>tannin</i>).....	C ₅₄ H ₂₂ O ₃₄
Oxalic acid	C ₄ H ₆
• Carbonate of soda (<i>sal-soda</i>)	NaO ₃ CO ₂
Hydrochloric acid (<i>muriatic</i>).....	HCl
Ammonia (<i>hartshorn</i>)	NH ₃
Nitric acid (<i>aquafortis</i>)	NO ₃
Potassa (<i>potash</i>)	KO
Sulphuric acid (<i>oil of vitriol</i>)	SO ₃

GALLIC ACID is always a companion of tannin in

the substances we have named, and is formed from it by exposure to the air. In some hair-dyes the hair is first wet with gallic acid, and then with a solution of nitrate of silver. The acid decomposes the salt, and the liberated oxyd of silver colors the hair.

OILS AND FATS.

The difference between oils and fats is only that of temperature; the former remain liquid at ordinary degrees of heat, while the latter is a solid. "A fat may be called a solid oil, and an oil a liquid fat," with equal propriety. The peculiar odor of each is due to some volatile acid. They are divided into two classes—fixed oils and volatile oils. The former produce a permanent stain on paper, the latter do not. "A cork twisted into the neck of a bottle containing a fixed oil makes no noise; in a volatile oil it squeaks."

THE FIXED OILS.

Constitution.—All fatty bodies are salts, being composed of *stearin*, *margarin*, and *olein*. These consist of three acids—*stearic*, *margaric*, and *oleic*, combined with a common base, *glycerin*; thus:

Stearic acid,	}	with Glycerin (as a base), form	Stearin.
Margaric acid,			Margarin.
Oleic acid,			Olein.

The first two of these salts are solids at common temperatures, and form fats; the latter is a liquid, and forms oils. The relative proportion of olein contained in any fatty substance determines its fluidity. Ex.: Stearin is abundant in tallow, and margarin in butter, hence their comparative consistency. Lard, on the other hand, contains so much olein that it is expressed in large quantities as "lard-oil." Olive-oil contains much olein and margarin; the former remains fluid at ordinary temperatures, but the latter, in cold weather, hardens into a thick deposit, and renders the oil extremely viscid.

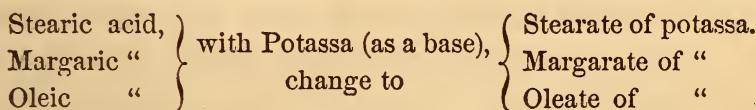
GLYCERIN is named from its sweet taste. It is made from tallow, and is an odorless transparent syrup. It is soluble in H_2O and alcohol. Its healing properties are remarkable, and its use is common in dressing sores, insect bites, chapped hands, etc. When highly heated it is decomposed, and produces an acrid substance (acroleine) with which we are familiar in the disagreeable smell of a smouldering candle-wick and burning fat.

By the action of NO_2 and SO_3 glycerin is converted into *nitro-glycerin*, an oil that explodes with most fearful violence by the slightest concussion, or even from unexplainable causes. It is used in blasting.

LYE is a strong solution of KO_2 , and is obtained, as we have seen, by leaching ashes. The alkali is contained in the ashes in the form of KO.CO_2 . At the bottom of the leach-tub a little lime is commonly

placed to absorb the CO_2 and leave the KO unneutralized by the acid, and therefore stronger.

HOME-MADE SOAPS are formed by heating "lye" and "soap-grease." In this process the potassa of the lye drives off the glycerin of the grease and makes new salts which contain KO, instead of glycerin, as the base; thus:



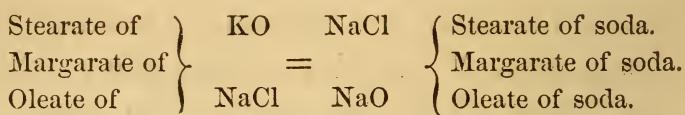
These three salts constitute soap. The expelled glycerin remains floating around alone through the mass. This soap is soft because of the attraction of KO for HO. The boiling merely hastens the chemical change. It takes place more slowly in the making of "cold soap."

HARD SOAP contains soda instead of KO as a base. This is not deliquescent,* and so the soap retains its solid form. Soda soap can be formed from potassa soap by the addition of common salt (NaCl).

Reaction.—The O of the potassa (KO) unites with the sodium (Na) of the salt (NaCl), forming soda (NaO). The chlorine (Cl) of the salt (NaCl) unites with the potassium (K) of the potassa (KO), forming chloride of potassium (KCl). The soda thus formed displaces the potassa, and makes a hard or soda

* A deliquescent body is one that dissolves in HO, which it absorbs from the air.

soap, while the KCl remains dissolved in the water; thus :

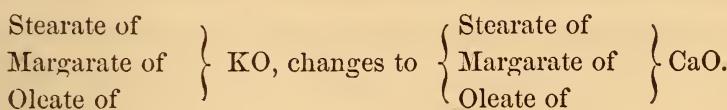


The kind of fat used, by the amount of olein it contains, also determines the softness of the soap. Ex.: Tallow makes a harder soap than lard, since it has less olein. Soap has a powerful affinity for HO, and will readily absorb 50 per cent. of its weight. It is therefore noticeable that dealers commonly keep their soaps in cellars or damp places. The best old soap contains at least 20 per cent.

FANCY SOAPS.—Castile soap is composed of olive-oil and soda. Its mottled appearance is caused by oxyd of iron, which is stirred through it in fanciful designs while it is yet soft. Yellow soaps contain rosin in part, instead of fat, forming a rosin soap. *Cocoanut-oil* makes a soap which will dissolve in salt water, and is therefore used at sea. It also forms a strong lather, and is sold as “shaving-soap.” *Washing fluids* contain an unusual amount of alkali, and are therefore apt to be injurious to the cloth. *Soap-balls* are made by dissolving soap in a very little water, and then working it with starch to a proper consistency to be shaped into balls. White toilet-soaps are made from lard and soda.

SOAP IN HARD WATER.—Water containing any mineral matter will not dissolve soap, since the lime,

magnesia, etc., displace the alkali in the soap, and form a new soap which is not soluble, but floats on top as a greasy scum. Example: A potassa soap in lime-water changes to a lime soap. Thus—



THE CLEANSING QUALITIES OF SOAP.—There exudes constantly from the pores of our skin an oily perspiration, and this, catching the floating dust, dries into a film of greasy dirt which will not dissolve in water. The alkali of soap combines with this oily substance and makes a soap of it, which is soluble. In addition to this the alkali also dissolves the cuticle of our skin, and thus produces the "soapy feeling," as we term it, when we handle soap.

SOAPSD consists of a thin film of soap filled with bubbles of air. It is an excellent remedy in almost all cases of poisoning, and where the exact antidote is not at hand should be taken immediately. Soap-bubbles are said to be only two-millionths of an inch in thickness.—(*Newton.*) They are thinnest at the top, as the water runs down the sides toward the bottom constantly. These falling films of water cause the refraction of light, and a beautiful play of colors.

ADULTERATION.—Soap is frequently contaminated

with gypsum, lime, pipe-clay, etc. These may be detected by dissolving a small piece in alcohol and noticing if there be any precipitate.

CANDLES are made from tallow, stearin, paraffine, wax, spermaceti, etc. Tallow candles and their manufacture are too well known to need description. *Stearin* or *adamantine* candles are moulded like ordinary candles. They are prepared from tallow or lard, which is first boiled with lime and so made into a soap. This soap is decomposed by sulphuric acid, which takes away the lime, forming sulphate of lime, which, being insoluble, sinks to the bottom, leaving the three acids of the fat floating upon the surface. The glycerin is also left by itself in the liquid, from whence it is removed and prepared for the market. The acids, when cool, are subjected to great pressure; the olein flows out, leaving the stearic and margaric acids as a milk-white, odorless, tasteless solid, which is commonly called stearin, since that acid is the principal constituent. *Paraffine candles* are made from coal-oil, as we have already described. *Wax candles* are manufactured by the following process. A large number of cotton wicks are hung upon a revolving frame with projecting arms. The wicks are fitted at the end with metal tags to keep the wax from covering that part. As the machine slowly turns, a man, standing ready with a vessel of melted wax, carefully pours a little down each wick in succession. This process continues until the candles are fed to the desired size.

They are then well rolled on a smooth stone slab, the tops cut by conical tubes, the bottoms trimmed, and they are ready for use. The large tapers burned in Catholic cathedrals are made by placing the wick on a sheet of wax, rolling it up till the right thickness is reached, when the candle is trimmed and polished as before.

Spermaceti candles are run from the white crystalline solid fat which is found with sperm oil in the head of the sperm whale.

WAX is found in nearly all plants. It forms the shiny coating of the leaves and fruit. Example: Lemon leaf, apple. Certain plants in Japan contain so much wax that it is separated by boiling and used for making candles. Bees gather the wax for the construction of their comb partly from flowers, and a part they manufacture from the sweet juices sipped from the flowers. Yellow beeswax is bleached by exposure in thin ribbons to the air.

LINSEED OIL is a *drying oil*, as it is termed—*i. e.*, it absorbs O from the air, and hardens by exposure. It is expressed from flaxseed, which furnishes about one-fifth of its own weight of oil. *Boiled oil* is made by boiling the crude oil with litharge (PbO) for several hours. The oxyd of lead combines with the gummy mucilage of the oil, which collects as a slimy sediment. Linseed oil is used in mixing paints and varnishes. Putty consists of linseed oil and chalk (*Whiting*) well mixed. Printers' ink is made by burning linseed oil until it becomes thick and viscid,

when lampblack is stirred in, to make it of the proper consistency.

COD LIVER OIL is extracted from the liver of the codfish. It contains I, Br, and P, and is much used as a remedy in Consumption.

CROTON OIL is made from the seeds of an Indian plant; and is used as a powerful purgative and for causing eruptions on the skin.

CASTOR OIL is extracted from the castor-oil bean. It is used as a purgative, and also in perfumery and hair-oils.

SWEET-OIL, or OLIVE-OIL, is an *unctuous oil*, i. e., it absorbs O on exposure to the air—not hardening like the drying oils, but remaining sticky, and after a time becoming rancid from the formation of disagreeable volatile acids. Sweet-oil is expressed from the olive fruit. In Europe it is extensively used instead of butter. It is employed as a machine-oil, although the coal-oils are now much preferred.

VOLATILE OILS.

The Volatile oils, unlike the Fixed, make no soaps, and dissolve readily in alcohol or ether. Their solution in alcohol forms an essence, hence the term "essential," by which they are frequently called.

Source.—They are principally of vegetable origin. They are found in the petals of a flower, as the violet; in the seed, as caraway; in the leaves, as mint; in the root, as sassafras; and sometimes

several kinds of oil are obtained from different parts of the same plant. Example: The flower, leaves, and rind of the orange-tree furnish each its own variety. The perfume of flowers is produced by these volatile oils; but how slight a quantity is present may be inferred from the fact that one hundred pounds of fresh roses will give scarcely a quarter of an ounce of Attar of Roses.

Preparation.—In the peppermint, the wintergreen, and many others the plant is distilled with water. The oils pass over with the steam, and are condensed in a refrigerator connected with the “Mint Still.” The oil floats on the surface of the condensed water, and may be removed. A small portion, however, remains mingled with the latter, which thus acquires its peculiar taste and odor, constituting what are termed “perfumed waters.” Example: Rose-water, peppermint-water. In some flowers, as the violet, jasmin, etc., the perfume is too delicate to be collected in this manner. They are therefore laid between woollen cloths saturated with some fixed oil. This absorbs the essential oil, which is then dissolved by alcohol. Oil of lemon is obtained from the rind of the fruit by expression or by digesting in alcohol. Example: A good essence is made by putting bits of lemon-peel in a bottle of alcohol.

COMPOSITION.— C_5H_8 is the common symbol of a large number of these oils. Thus the oils of lemon, juniper, citron, black pepper, copaiba, bergamot,

turpentine, cubebbs, and oranges, are isomeric. A second class contains, besides C and H, a little O; a third, in addition, has S.

FIRST CLASS OF VOLATILE OILS.—Turpentine is a type of this division. It is made by distilling pitch with HO. It is generally called *spirits of turpentine*. It is highly inflammable, and, owing to the excess of C, burns with a great smoke. By the union of an atom of its H with an atom of the O of the air to form HO, it is converted into rosin. In this way, when exposed in bottles half full, the turpentine around the nozzle becomes first sticky and then resinous. Old oil should not be taken to remove grease spots, as, while it will remove one, it will leave another of its own. *Camphene* is turpentine purified by repeated distillation. *Burning-fluid* is a mixture of camphene and alcohol. In the heat of the burning H of the latter, the C of the former is consumed, and this produces a bright light. The tendency of camphene to smoke is thus diminished, and the illuminating power increased. By the action of HCl on turpentine or oil of lemons an artificial camphor is produced very nearly resembling our common camphor.

THE SECOND CLASS includes the oils of bitter almonds, cinnamon, peppermint, roses, lavender, etc. They are sometimes called "The Camphors," because of their general resemblance to the crystalline essence known by that name. Camphor ($C_5H_8O_2$) is obtained by distilling the roots and leaves of the camphor-

tree of Japan in water, and condensing the vapors in rice-straw. It is purified by sublimation. When kept in a bottle, it vaporizes, and its delicate crystals collect on the side toward the light. Taken internally, except in small doses, it is a virulent poison. Its solution in alcohol is called spirits of camphor. If HO be added to this, the camphor will be precipitated as a flour-like powder.

THE THIRD CLASS contains S, and sometimes N. It includes garlic, assafoetida, hops, onions, mustard, horseradish, etc. They are known for their pungent taste and the disagreeable odor they often impart to the breath. The oil of mustard is not contained in the seed, but is formed in it by the action of water and a latent ferment. This is the reason why mustard, when first prepared for the table, is bitter, but becomes pungent after a little time.

RESINS AND BALSAMS.

Resins are formed from the essential oils by oxydation. Example: *Turpentine*, as we have just seen, is changed to rosin, a resinous substance. If the resin is dissolved in some essential oil it is called a balsam. Example: *Pitch* is a true balsam, since by distillation it is separated into rosin and turpentine.

Source.—They mostly exude from incisions in trees and shrubs, in the form of a balsam, which oxydizes on exposure to the air, and becomes a resin. Example: Common plum-tree, pine-tree.

Properties of Resins.—They are translucent, brittle, insoluble in HO, but soluble in ether, alcohol, or any volatile oil, are non-conductors of electricity, and burn with much smoke. They do not decay, and, indeed, have the power of preserving other substances. For this reason they were used in embalming the bodies of the ancient Egyptians, which, after the lapse of two thousand years, are yet found dried into mummies in their mammoth tombs—the Pyramids.

ROSIN constitutes about 75 per cent of pitch. It is used in making soaps, to increase friction in violin bows and the cords of clock-weights, in soldering, and as a source of illuminating gas. Shoemakers' wax is made by burning rosin until partly charred.

LAC exudes from the ficus-tree of the East Indies. An insect punctures the bark, and the juice flows out over the insect, which works it into cells in which to deposit its eggs. The twigs incrusted with the dried gum is called *stick-lac*, when removed from the wood it is *seed-lac*, when melted and strained, *shellac*. The liquefied resin is dropped upon large leaves, and so cools in broad thin pieces, as we buy it. *Sealing-wax* is made of shellac and turpentine; vermillion is added to give the red color. Shellac is much used in making varnishes.

GUM BENZOIN also exudes from a tree in the East Indies. It contains benzoic acid. It is used in fumigation, in cosmetics, and on account of its fragrant odor is burnt as incense. Ex.: Place some green sprigs under a glass receiver, and at the bottom a hot iron, on which sprinkle a little benzoic acid. It will sublime and collect in beautifully delicate crystals on the green leaves above, making a perfect illustration of winter frost-work.

AMBER is a fossil resin which has exuded in some past age of the world's history from trees now extinct. It is sometimes found containing various insects perfectly preserved, which were without doubt entangled in the mass while it was yet soft. These are so beautifully embalmed in this transparent glass that they give us a good idea of the insect life of that age. It is cast up by the sea, in pieces of a few ounces each, on the shores of the Baltic and off the coast of New Jersey. It is commonly translucent, and susceptible of a high polish. It is used for ornaments, mouth-pieces, necklaces, buttons, etc. It is a prominent ingredient in carriage varnish.

CAOUTCHOUC or INDIA-RUBBER is a pure hydro-carbon, and may be considered as hardened illuminating gas. It exudes from certain trees in South America as a milky juice. The globules of rubber are suspended in it as butter is in milk. By adding ammonia the sap may be kept unchanged for months, and is sometimes exported in that form preserved in tightly corked bottles. The tree, it is said, yields

about a gill per day from each incision made. A little clay cup is placed underneath, from which the juice is collected and poured over clay or wooden patterns in successive layers as it dries. To hasten the process it is carried on over large open fires, the smoke of which gives to the rubber its black color ; when pure it is almost white. When nearly hard the rubber will receive any fanciful design which may be marked upon it with a pointed stick. The natives often form the clay into odd shapes as bottles, images, etc., and the rubber is sometimes exported in these uncouth forms. The solvents of rubber are ether, naphtha, coal-oil, turpentine, benzole, etc. It melts, but does not become solid on cooling. It loses its elastic power when stretched for a long time, but recovers it on being heated. In the manufacture of rubber goods for suspenders, etc., the rubber thread is drawn over bobbins and left for some days until it becomes inelastic. In this state it is woven, after which a hot wheel is rolled over the cloth to restore the elasticity.

VULCANIZED RUBBER is made by heating caoutchouc with a small amount of sulphur. This constituted Goodyear's original patent, and was discovered accidentally. While engaged in experimenting upon improvements in this branch of manufacture, he was one day talking with a friend and happened to drop a bit of sulphur in a pot of melted rubber. By one of those happy intuitions which seem to come only to men of genius, he watched tho

result, and discovered—"Vulcanized Rubber!" It is less liable to be hardened by cold or softened by heat, and admits of many uses to which common rubber would be entirely unsuited. When, in addition, it is mixed with pitch and magnesia, it becomes a hard brittle solid, capable of a high polish, and is used for knife-handles, combs, and brushes.

GUTTA-PERCHA resembles caoutchouc in its source, preparation, and appearance. It softens in warm water, and can then be moulded into any desired shape. When cooled it assumes its original solidity. It is extensively used in taking impressions of medals, etc.

ORGANIC BASES

The organic bases, or alkaloids, as they are called, are the bases of true salts found in plants. They dissolve slightly in HO, but freely in alcohol. They have a bitter taste, and rank among the most fearful poisons known. The antidote is tannin, which forms with them insoluble tannates. Any liquid containing it is of value—as strong green tea—and should be immediately administered in a case of poisoning by any of the alkaloids.

OPIUM is the dried juice of the poppy plant, which is extensively cultivated in Turkey for the sake of this product. Workmen pass along the rows soon after

the flowers have fallen off, cutting slightly each capsule. From this incision a milky juice exudes and collects into a little tear. In twenty-four hours these are gathered and beaten up in an earthen jar with saliva to the proper consistency, when the mass is wrapped in leaves for the market. It is afterward purified.

Properties.—Opium produces a powerful influence on the nervous system. It stimulates the brain and excites the imagination to a wonderful pitch of intensity. The dreams of the opium-eater are said to be vivid and fantastic beyond description.* The dose must be gradually increased to repeat the effect, and the result is most disastrous. The nervous system becomes deranged, and no relief can be secured save by a fresh resort to this baneful drug. Labor becomes irksome, ordinary food distasteful, and racking pains torment the whole body. No person can be too careful in the use of a narcotic whose influence is liable to become so destructive.

OPIUM-SMOKING.—In China the custom of smoking opium is fearfully prevalent. The opium is made into a thick syrup with water. A small portion is placed in the bowl of the pipe, which is held in the flame of an oil-lamp until the opium is partly volatilized and fully ignited. During this process, the smoker, reclining upon his side, gently inhales the fumes, and absorbs them by retaining them until they slowly pass out through the nose. Opium-shops

* See APPENDIX.

are said to be more numerous in China than even rice-shops. The effect is worse than that of intoxicating liquors, if it is possible to compare two such fearfully pernicious vices.

MORPHIA.—*Morphine* is one of the alkaloid bases of opium. It is so called from Morpheus, the god of sleep. It is a bitter, narcotic, resinous-like substance. It is used principally as a sulphate of morphia, in doses of one-eighth to one-fourth of a grain, to alleviate pain and produce sleep. *Laudanum* is the tincture of opium. *Paregoric* is a camphorated tincture of opium, with benzoic acid and oil of anise.

QUINIA.—*Quinine* is prepared from Peruvian bark. It is employed in medicine as a tincture of Peruvian bark, or in the form of sulphate of quinia, for cases of fever and ague and all periodic diseases.

NICOTINE is the active principle of the tobacco plant. It is volatile, and passes off in the smoke. A drop will kill a large dog. It probably produces the ill effects that follow the use of tobacco.

STRYCHNIA.—*Strichnine* is prepared from the nux vomica bean, obtained from a small tree in the East Indies. The “woorara,” with which the South American Indians poison their arrows, is a variety of strychnine. This is so deadly that the scratch of a needle dipped in it would produce death. Strychnine is scarcely soluble in water, but freely in the essential oils and chloroform. It is so intensely bitter that one grain will impart a flavor to twenty-

five gallons of water. One-thirtieth of a grain has killed a dog in thirty seconds, while half a grain is fatal to a man.

The *Chromatic Test* consists in placing on a clean porcelain plate a drop of the suspected liquid, a drop of SO_3 , and a crystal of bichromate of potassa. Mix the three very slowly with a clean glass rod. If there be any strychnine present, it will change the color into a beautiful violet tint, passing into a pale rose. It is, however, one of the most difficult poisons to detect. Arsenic was formerly used by the poisoner, but Marsh's test infallibly reveals its presence in the body of the victim, even after many years have elapsed. But the organic poisons are so easily acted upon by the fluids of the system, that in one case, though four grains were taken, and death ensued very quickly, yet the "chromatic test" failed to reveal the presence of any strychnine in the stomach. However, the murderer is not to escape. This is the only poison except brucite (and that also is extracted from *nux vomica*) that produces tetanus or lock-jaw. This symptom infallibly proves to the physician that death has been caused by strychnine. To prove this conclusively, a tiny frog is brought into the court-room and made to show the effects of the poison. So sensitive is this gentle reptile, that a few drops of oil containing only $\frac{1}{100,000}$ of a grain will instantly throw him into the most rigid locked-jaw, in which he is incapable of producing a single croak.

COFFEINE AND THEINE constitute the active prin-

ciple of tea and coffee, and are isomeric. They crystallize in beautiful white prisms of a silky lustre. In addition, tea contains from 12 to 18 per cent. of tannic acid, some 15 per cent. of gluten, which is lost in the "grounds" (unless we imitate the Japanese and eat them with the tea), and a volatile oil which gives to it its peculiar aromatic odor and taste. Coffee contains 14 per cent. of a fixed oil, and also an essential oil which is developed in roasting, and is remarkably volatile, so that it soon escapes unless the coffee is kept tightly covered.

Tea-raising.—The tea-plants are allowed to grow only about a foot and a half high, and resemble in some respects the low whortleberry bush. They are grown in rows, three to five in a hill, very much as corn is with us. The medium-sized leaves are picked by hand, the largest ones being left on the bushes to favor their growth. Each little hill or clump will furnish from three to five ounces of green leaves; or about one ounce of tea in the course of the season. The leaves are first wilted in the sun, then trodden in baskets by barefooted men to break the stems, next rolled by the hands into a spiral shape, then left in a heap to heat again, and finally dried for the market. This constitutes BLACK TEA, and the color would be produced in any leaves left thus to wilt and heat in heaps in the open air. The Chinese always drink this kind of tea. They use no milk or sugar, and prepare it, not by steeping, but by pouring hot water on the tea and allowing it to stand for

a few minutes. Whenever a friend calls on a Chinaman, common politeness requires that a cup of tea be immediately offered him.

Green Tea is prepared like black, except that it is not allowed to wilt or heat, and is quickly dried over a fire. It is also very frequently, if not always, colored, cheap black teas and leaves of other plants being added in large quantities. In this country, damaged teas and the "grounds" left at hotels are re-rolled, highly colored, packed in old tea-chests, and sent out as new teas. Certain varieties of black tea even receive a coating of black-lead to make them shiny.

There are various other alkaloids that are worthy of mention merely. Lettuce contains one similar to opium, which gives it a slight narcotic influence. Aconite is obtained from monk's-hood, veratrine from the hellebore, solanine from the henbane, piperine from white, black, and long peppers—isomeric in white needle-shaped crystals.

ORGANIC COLORING PRINCIPLES.

With the exception of cochineal, all the organic coloring principles are of vegetable origin. The beautiful tints of flowers are so evanescent that they cannot be retained. Coloring matters are therefore taken of soberer hue from the interior of plants, where they are less exposed to the light.

DYEING.—Very few of the colors have such an

affinity for the fibres of the cloth that they will not wash out. Such as, like indigo, will dye directly are called *substantive* colors. But the majority require a third substance which has an attraction for both the coloring matter and the cloth, and will hold them together. Such substances are called *mordants* (from *mordeo*, to bite), because they bite the color into the cloth. The most common mordants are alum, oxyd of tin, and copperas. In dyeing, the cloth is first dipped in a solution of the mordant, and then of the dye-stuff. Ex.: If a piece of cotton cloth be dipped in a decoction of madder, it will receive an unstable dirty red color. If, however, it be soaked first in a solution of alum and sugar of lead ($PbO\cdot\bar{A}$), the acetate of alumina will be formed in its fibres, and will act as a mordant. Now dip it into the same dye, and it will come out a brilliant red—a “fast color.” The mordant, by means of a stamp, may be applied to the cloth in the form of a pattern, and when it is afterward washed, the color will all be removed except where the mordant fixed it in the printed figure. The same dye will produce different colors by a change of mordants. Ex.: Logwood and copperas will dye black; logwood and tin, a violet. Madder will dye in this way red, purple, yellow, orange, and brown. This principle lies at the basis of dyeing “prints.”

CALICO-PRINTING.—A calico-printing machine is very complex. The cloth passes between a series of rollers, upon which the corresponding mordant is

put, as ink is on type. A single machine sometimes prints from twenty sets of rollers ; yet each impression follows the other so accurately, that when the cloth has passed through, the entire pattern is printed upon it with the different mordants more perfectly than any painter could do it, and so rapidly that a mile of cloth has been printed with four mordants in an hour. The cloth when it leaves the printing machine, though stamped with the mordants in the form of the figure, betrays nothing of the real design until after being dipped in the dye, which acting on the different mordants brings out the desired colors. The print is now washed, glazed, and fitted for the market.

RED AND VIOLET COLORING SUBSTANCES.—*Madder* is the root of a plant found in the East Indies. When first dug it is yellow, but by exposure to the air it absorbs O and becomes red. It is used in dyeing the brilliant Turkey-red. *Cochineal* is an insect that preys upon a species of cactus in Central America. It is raised in large plantations, dried between hot iron plates, and exported as an article of commerce. It yields the brightest scarlet and purple dyes. The *purple* of which we read in ancient writings was a secret with the Tyrians. King Huram, we learn, sent a workman to Solomon skilled in this art. The dye was obtained from a shell-fish that was found on the coast of Phoenicia. Each animal yielded a tiny drop of the precious liquid. A yard of cloth dipped twice in this costly dye was worth \$150.

Brazil-wood furnishes a *red* which is not very permanent. It is used for making red ink. Experiment: Boil 2 oz. of Brazil-wood in a pint of HO for fifteen minutes, then add a little gum-arabic and alum.

BLUE COLORING SUBSTANCES.—The *indigo* of commerce is obtained from a bushy plant found in Asia. The juice is colorless, but by fermentation for some days, in vats of water, a yellow substance is formed, which by exposure to the air absorbs O, and changes to a deep blue. By any deoxydizing agent the color of indigo may be removed at pleasure. Example: Add to a test-tube of boiling HO, colored with a solution of indigo,* a drop of NO₅. The blue color will instantly disappear. *Litmus* is obtained from certain kinds of lichens, which grow on the rocks along the coasts of France and England. The juice is colorless, like the other dye-plants, but assumes a rich purple blue by the addition of ammonia (NH₃).

GREEN COLORING SUBSTANCE.—Leaf-green, as found in plants, is a waxy substance, containing several coloring matters. It seems to lie in the cells of the leaf in minute crystals, and to be formed by the action of the sunbeam. Plants removed from a dark cellar to the open air grow green rapidly.

* To make this solution, mix a little pulverized indigo into a paste with SO₃. Let it stand a few days, then add HO at pleasure.

ALBUMINOUS BODIES.

The Albuminous bodies differ essentially from any yet named. They are far more complex in their structure, contain more nitrogen, and do not crystallize. The most important are—

Albumen,
Fibrin,
Casein.

These are isomeric, and, when taken into the system, are all changed into albumen before leaving the stomach. When decomposed by an alkali they yield a white inodorous solid, which will act as a base and form salts. This is called “Protein” (*proteuo*, I am first), and these substances themselves are termed the *protein compounds*. Their composition is very complex, as may be seen from the following table given by Liebig:

Albumen of blood.....	.....	}
Albumen of flesh.....	.....
Fibrin of flesh.....	.....
Albumen of eggs.....	$C_{216}H_{169}O_{68}N_{27}S_2$.	
Casein.....	$C_{288}H_{228}O_{90}N_{36}S_2$.	
Fibrin of blood.....	$C_{298}H_{228}O_{92}N_{40}S_2$.	

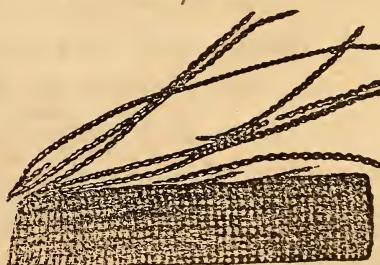
ALBUMEN.—Sources.—It exists nearly pure in the whites of eggs—hence the name (*albus*, white); also in the serum—the transparent part of the blood—and the juices and seeds of many plants.

Properties.—It is soluble in cold, but insoluble in

hot HO. At a temperature of 145° F. it coagulates. This change we always see in the cooking of eggs. Alcohol, corrosive sublimate, acids, creosote, etc., have the power to coagulate albumen. In cases of poisoning by these substances it is therefore a valuable antidote, as it wraps them up in an insoluble covering, and so protects the stomach. Albumen seems to have the properties of an acid and a base. It coagulates with an acid by uniting with it as a base. It coagulates with a salt by uniting with its base as an acid. It exists in two amorphous conditions—as a liquid in the sap of plants, the humors of the eye, serum of blood, etc.; as a solid in the seeds of plants and the nerves and brains of animals.

Vegetable Albumen.—If the water used in making starch from potatoes be boiled, it will become turbid and deposit a flaky white substance identical with the whites of eggs, and therefore named vegetable albumen.

FIBRIN constitutes chiefly the fibrous portion of the muscles. If a piece of lean beef be washed in clean HO until all the red color disappears, the mass of white tissue which will remain is called fibrin. Like albumen, it exists in two forms—as a liquid in the blood, and as a solid in flesh and the seeds



Fibrin, or Muscle.

of plants. The clotting of blood is due to the coagulation of the fibrin.

Vegetable Fibrin—Gluten.—If wheat flour be made into a dough, and then kneaded in water until all the soluble portion is washed away, the tough glutinous mass which will remain is called *gluten*. It is identical in composition with fibrin, and is therefore named vegetable fibrin. We obtain it as a gum when we chew wheat, thereby dissolving the starch. It exists most abundantly in the bran of cereal grains.

Example : Wheat.

CASEIN is found in the curd of milk (whence the name, *caseum*, cheese), in the blood, peas, and beans. The curdling of milk is due to the coagulation of its casein. When milk sours, its lactic acid combines with the alkali present, and precipitates the casein, which is only soluble in HO containing some alkali. The rennet (the dried stomach of a calf), used in making cheese, acts in the same manner.

Vegetable Casein.—By treating peas as we do potatoes in forming starch, and then adding a little acid to the water which is left after the starch settles, an albuminous substance is deposited, which is identical with casein, and has received the name *vegetable casein*. The Chinese use it largely for cheese.

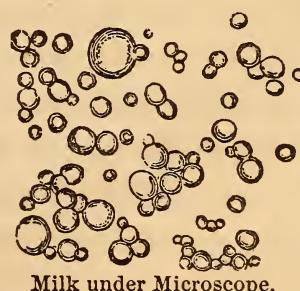
GELATIN.—Hot water dissolves a substance from animal membranes, skin, tendons, and bones, which, on cooling, forms a yielding tremulous mass called gelatin. As calves-foot jelly, soups, etc., it is well known. As an article of food it is of very little nu-

tritive value. It may answer to dilute a stronger diet, but of itself does little to build up the body of an invalid. Beef-tea is by far more strengthening than jellies or blanc-mange. *Glue* is a gelatin made from bones, hoofs, horns, etc., by boiling in HO and then evaporating the solution. *Isinglass* is the purest gelatin, and is obtained from the air-bladders of the cod, sturgeon, and other fish. *Size* is gelatin prepared from the parings of parchment, the thinnest kind of skins. It is used for sizing paper to fill up the pores and prevent the ink from spreading, as it does on unsized or blotting-paper.

Vegetable Gelatine is familiar to us in the form of blanc-mange and the fruit-jellies. It is nearly like starch or grape-sugar in its composition. It is called Pectine (see page 159). It is found in Iceland moss, grapes, apples, quinces, and other fruits.

MILK is a natural emulsion, composed of exceedingly minute globules diffused through a transparent liquid. The globules consist of a thin envelope of casein filled with butter.

Being a trifle lighter than HO, they rise to the surface as cream. Churning breaks these coverings, and gathers the butter into a mass. Milk contains some sugar, and this, by the action of



the O of the air changes to lactic acid, which gives the peculiar taste to sour milk. The casein seems to act as a ferment in hastening this oxydation. In

churning, the cream always "turns," because O is rapidly absorbed as the milk is stirred, and lactic acid formed. Milk sours in the stomach by the action of the acids, which convert it into lactic acid.

BONES consist of organic and mineral matter combined.

ANALYSIS. (*Berzelius.*)

Gelatin—(Gluten).....	32.17
Blood-vessels	1.13
Phosphate of lime.....	51.04
Carbonate of lime.....	11.30
Fluoride of calcium	2.00
Phosphate of magnesia.....	1.16
Chloride of sodium	1.20
	<hr/>
	100.00

By soaking a bone in HCl the mineral matters will all be dissolved, and the organic matter left in the original shape of the bone, but soft and pliable. If, instead, the bone be burned in the fire, the organic matter will be removed and the mineral left white and porous. The blood circulates freely through the bones, however hard they may seem to be. If a little madder be mixed with the food of pigs, it will tinge red all their bones. If the madder be given at considerable intervals, it will make streaks of white and red bone alternately.

Putrefaction.—Owing to the complex structure of albuminous substances, and the presence of the fickle

nitrogen, they readily oxydize and form entirely new compounds. This breaking up is called putrefaction. The P and S present in flesh especially, take up the H in hot haste, and flying off as sulphuretted hydrogen (HS) and phosphuretted hydrogen (PH_3), salute our olfactories with their well-known odors. These poisonous and offensive gases abounding near slaughter-houses and similar establishments, make them so unhealthy. Any portion of an albuminous substance thus putrefying may act as a ferment. This probably explains the danger physicians incur in dissecting a dead body. The least portion of the decomposing matter entering their flesh, through a scratch even, is liable to be fatal. The presence of an albuminous substance always hastens decay. The white, or sap wood, contains some N, and so this rots very quickly. Timber steeped in a solution of corrosive sublimate (kyanized) is rendered almost indestructible, because that salt coagulates the albumen. The absence of HO retards chemical change, and therefore meats, apples, etc., are preserved by drying. Salt acts somewhat in the same way by absorbing the juice of the meat, and, while it covers it as brine, wards off the attacking O; but as it dissolves some of the salts and other valuable elements of the meat, it makes it less nutritious.

DOMESTIC CHEMISTRY.

In the chemistry of housekeeping there are some points not yet spoken of, and they may now be profitably discussed.

MAKING BREAD.—Flour consists of gluten, starch, and a little gum and sugar. There is also about two per cent. of ash, about one half of which is phosphate of lime; but these mineral constituents are found mainly in the bran. In mixing the “sponge,” the process is purely mechanical. The water used moistens the starch, dissolves the albumen, sugar, and gum, and causes the gluten to cohere. When the sponge is set aside in a warm place to rise (as heat favors chemical change), the yeast, yeast-cake, or emptyings, as the case may be, induces a rapid fermentation, converting the sugar into alcohol and CO_2 . This gas is diffused through the mass, and struggles to escape, but is retained by the tenacious and viscid dough, causing it to “rise.” The next step includes the addition of fresh flour, and a laborious process of “kneading.” The latter, so essential to good bread, diffuses the half-fermented sponge uniformly through the dough, and thus spreads the continued fermentation throughout the loaf; it also breaks up into smaller ones the bubbles of gas entangled in the gluten, and thereby makes the bread

fine-grained. The dough is now "moulded" into loaves. When placed in the hot oven, the first effect is to increase the fermentation. Some of the starch is turned into sugar to supply material, the heat expands the CO₂, changes the alcohol to vapor and the water to steam. All these by their expansive force rapidly increase the size of the loaf. When the whole loaf has been heated to about 350° F., the fermentation is checked, and if the temperature of the oven is right, the cells of the bread will have sufficient strength to retain their form after the gas and vapors have escaped. If the heat is not sufficient, or if there is too much water in the dough, the CO₂ escapes, and the cells, not having hardened sufficiently, collapse, and the bread is "slack-baked." If the oven is too hot, a crust forms over the surface of the loaf, which prevents the escape of the CO₂, so it accumulates at the centre, making the bread hollow. A part of the starch in the crust is converted by the heat into gum (dextrine), and if it be burnt, this is disorganized, the volatile gases driven off, and the carbon left. A shiny coat is given to the loaf ("rusk") by moistening the crust after the bread is baked, thus dissolving some of the gum, which quickly dries on returning it to the oven.

Milk-emptyings is sometimes used in making bread. In this case, the mixture of flour and milk, kept at a temperature of 90°, develops yeast, which produces fermentation. If the heat is over 90°, the yeast plant is killed; if lower, it is not formed. In the

latter case, the milk is merely turned to lactic acid. Oftentimes, too, the side of the dish, near the fire, may be warm enough to produce yeast and to generate CO_2 and alcohol, while on the opposite side lactic acid is being formed. A uniform temperature is necessary, and this can best be obtained by placing the dish of emptyings in a kettle of warm water on the stove hearth, where the temperature can be kept very near the requisite 90° .

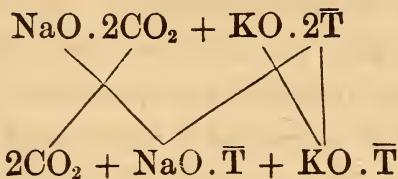
STALE BREAD.—New bread consists of nearly one half water. In stale bread this disappears. It has, however, only combined with the solid portions chemically, and may be brought to view by heating the loaf in a close tin vessel.

AERATED BREAD is not “raised” by fermentation, but by means of CO_2 , which is forced into it by great pressure.

SOUR BREAD is caused by the first stage of the fermentation not being stopped soon enough, and the second stage commencing, in which acetic acid is formed. This may be neutralized by an alkali, as saleratus ($\text{KO} \cdot 2\text{CO}_2$), or soda ($\text{NaO} \cdot 2\text{CO}_2$).

PAN-CAKES are raised by the addition of some ferment, as yeast, but the second, or acetous stage, is always reached. The “batter” now tastes sour, and is sweetened by saleratus or soda. The acetic acid combines with the KO (if saleratus is used), forming acetate of potassa, a neutral salt which remains, and the CO_2 bubbles up through the batter, making it “light.”

RAISING BISCUIT.—In raising biscuit or cake, soda and cream of tartar are most commonly used. The latter is a bitartrate of potassa, and the reaction is as follows :



Cream of tartar is now often adulterated with plaster, lime, chalk, or flour. By dissolving in water these can be detected, as they form an insoluble precipitate ; but in milk, as commonly used in cooking, they are not noticed. Common “baking-powders” contain simply cream of tartar and soda. Professor Hosford’s powders are scientific. They contain phosphate of lime and soda. The reaction is the same as that just described, while phosphates of lime and soda are formed, both of which are materials for bone-making. Soda and HCl are also used in baking. By heat both constituents are resolved into HO, CO₂, and NaCl. The HO and CO₂ raise the bread, while the common salt seasons it. There is a difficulty in procuring pure acid and in mixing the ingredients in their combining proportions.

Bread Dietetics.—It is doubtful whether ordinary yeast-powders or cream of tartar and soda make as healthy food as the regular process of fermentation. There is frequently a portion of the powders left un-

combined, and always a salt formed which may injure the gastric juice. Sometimes, indeed, we find biscuit and cake yellow, and even spotted with bits of saleratus ; yet such food must be “eaten to save it.” A most wretched mistake ! Better throw away pans of cake and biscuit than torment Nature with such nauseous, poisonous preparations. Sal-volatile or carbonate of ammonia is often used by bakers for raising cake. This should volatilize into two gases, NH_3 and CO_2 , on the application of heat, but in practice a portion is left commonly hidden in the cake to work injury to the inoffensive stomach.

TOASTING BREAD.—By toasting bread it becomes much more digestible, as the starch is converted largely into gum, which is soluble. The charcoal which may be formed when the heat has disorganized the bread and driven off the water, also acts favorably on the stomach by absorbing in its pores noxious gases, as in “crust coffee.”

COOKING POTATOES.—A raw potato is indigestible, but by cooking, the starch granules absorb the water of the potatoe, burst, and make it “mealy.” If the potatoe contains more HO than the starch can imbibe, it is called “watery.”

COOKING MEAT.—All fried food is unhealthy, since the fat is partly disorganized by the heat, and therefore becomes rancid on the stomach. Broiling and boiling are the most preferable methods of cooking. In the former no butter should be used, and the juices should not be pressed out of the meat, but the heat

should be intense enough to sear over the outside instantly, and prevent "dripping" on the coals. In the latter, the water should boil when the meat is put in, so as to coagulate the albumen upon the outside, close the pores, and thus keep the juices of the meat within, otherwise it will become tough, and much also of its value will be lost. In making soup, on the contrary, as the object is to extract the juices of the meat, cold water should be used. It should be heated slowly, and boiled only for a few moments just before it is taken off from the fire. Long continued boiling would coagulate that which should remain dissolved in the soup. In baking, the oven should be very hot at first, to prevent the meat from becoming dry and unsavory. When meat burns, the heat has become so intense as to disorganize the flesh, driving off the HO and volatile gases, and leaving the C.

WATER IN COOKING.—The solvent power of soft water is greater than that of hard water. For this reason, in making soup, tea, etc., the former should be used; in boiling meats and cooking vegetables, where the object is not to extract the flavor or juices, the latter is preferable. Sometimes in cooking very delicate vegetables, as onions, the hardness of the water must be increased by adding salt to prevent their sweetness from dissolving. Salt is not put into vegetables, when boiling them, so much to flavor them as to preserve their aroma, which, if lost, no subsequent salting will restore. Peas and beans will not

cook soft in hard water, because the mineral matter hardens the casein they contain. A soup cannot be made of salt meat.

QUANTITY OF FOOD REQUIRED.—To repair the constant waste of the body, we each require about 800 lbs. of food, 1500 of water, and 800 of oxygen per annum. A ton and a half of material is thus needed each year to preserve intact our corporeal system. We take in each day about 10 lbs. of matter, yet may not gain an ounce in weight. This large amount passing through the mould of our body is all burned—*i. e.*, combines with O. This must be a renewed proof of the statement made under the subject of oxygen, that the vital principle does not prevent decay, but only regulates it, and that the moment we begin to live we begin to die.

THE EFFECT OF FOOD.—There is an ancient saying, “Tell me what a man eats and I will tell you what he is.” A man’s mind sympathizes so intimately with his body, that through the body the soul itself may be gradually animalized by gross food. The coarse feeder and the fine feeder become as different in their feelings as they are in their food. Animal food inflames; vegetable, calms. The passionate require a vegetable diet, while the phlegmatic may stimulate with flesh. Compare, for example, the dreamy vegetarian Hindoo with the fierce, meat-eating Indian.

THE DIVISIONS OF FOOD.—All food is divided into two general classes—“*cell-making*” and “*muscle-*

making," or respiratory and nutritive. The former comprises all such articles as are burned in our corporeal stove, as wood is in a furnace, mainly to produce heat. Example : Alcohol, starch, sugar, gum, fat, butter, etc. The latter includes such as are transformed into flesh and bone, and thus build up our bodies in some manner. Example : Lean meat, bread, milk, etc. Each of these contains a mixture of both to a certain extent, but is mainly either respiratory or nutritive. Example : Fat is deposited in cells which are probably nutritive, and, on the other hand, bread contains starch, which is respiratory.

NUTRITIVE VALUE OF FOOD OF DIFFERENT KINDS.—The following table, from Liebig, illustrates this subject :

	Nutritive.	Respiratory.
Cows' milk.....	1	3.
Beans.....	1	2.2
Peas.....	1	2.3
Fat mutton.....	1	2.7
Fat pork.....	1	3.
Beef.....	1	1.7
Veal	1	.1
Wheat flour.....	1	4.6
Oat meal.....	1	5.
Rye flour.....	1	5.7
Barley.....	1	5.7
Potatoes (white).....	1	8.6
Potatoes (blue).....	1	11.5
Rice.....	1	12.3
Buckwheat.....	1	13.

Sugar, alcohol, oil, etc., are heating and fattening. They make no muscle, no brain, no nervous tissue.

The bran of wheat contains largely the mineral matter we need for our bones and teeth and the nutritive food for our muscles. The whiteness of fine flour ("bolted" from its bran) is given to it by its starch. Our bones and muscles call loudly for the flour unbolted, as Nature designed it to meet our wants. Pork is only half as nutritious as beef, and is hence worth for work only half price. Besides, the hog is a filthy animal, a gross feeder, and subject to so many cutaneous diseases, that he will even stop eating for the luxury of being scratched. Its flesh was doubtless never designed for Yankee any more than for Jew. The workman gains strength, not from the pork he eats, but the turnips, cabbage (in its composition so near to beefsteak), milk, eggs, and other plastic or nutritive food.

CLIMATE PRESCRIBES THE KIND OF FOOD.—The Esquimaux Indian, with a climate many degrees below zero, needs much fire in his stove; so he lives mainly on fats. Tallow candles constitute his sweet-meats—twelve pounds making a luxurious dessert. Dr. Kane tells us that they would steal the half-burned wicks out of his candlesticks and draw them slowly between their teeth, to secure the adhering grease. Indeed, their idea of heaven is said to be that there the righteous will live in ice-huts, and feast forever on blubber. An American living in the Arctic regions soon acquires much of an Esquimaux's love for fats and oils. Nature has providentially provided there that kind of food, and not much else. Turn now to

the tropics, where the temperature is so high that all one's attention is taken up in keeping cool, and we find an entire change in the diet of the inhabitants. The natives confine themselves almost entirely to vegetables, and with this watery fuel reduce the heat of their bodies to the lowest point.

A MIXED DIET REQUIRED.—Nature seems to prescribe a mixed diet, to supply both wants of the system, and has, to some extent, mixed them herself in the various kinds of food. The Frenchman eats oil on his salad, the Yankee bakes beans with his pork, the Italian begs a bit of cheese for his maccaroni, the Irishman drinks buttermilk with his potatoes, the Hindoo pours rancid butter on his rice, while the Chinaman seasons his with pea cheese. No amount of starch or fat would support life. A man would starve on sugar or butter alone. The nitrogenous or nutritive element must be added. The season also regulates our diet. In the winter the highly respiratory buckwheat, with butter and syrup, is perfectly palatable, while in summer acid drinks, watery vegetables, and a simple unstimulating diet is equally enjoyed.

CONCLUSION.

CHEMISTRY OF THE SUNBEAM.—All those various plant products of which we have spoken in Organic Chemistry, when burned, either in the body as food or in the air as fuel, give off heat. This was garnered in the plant while growing, and came from that great source of heat—the sun. Thus all vegetation contains the latent heat of the sunbeam, ready to be set free upon its own oxydation. The coal even, derived as it is from ancient vegetation, hidden away in the earth, is thus a mine of reserved force. Those black diamonds we use as fuel become, in the eye of science, crystallized sunbeams, fagots of force, ready to impart to us at any moment the heat of some old carboniferous day. As we warm ourselves by our fires, or sit and read by our oil and gas lights, how strange the thought that their light and heat streamed down upon the earth ages ago, were absorbed by those grotesque leaves of the old coal forests, and kept safely stored away by a Divine care, in order to provide for our comfort! To carry the idea still further, we see that the present warmth of our bodies all comes from the same source—the sun. It mostly fell in the sunbeams of last summer upon our gardens and fields, was preserved in the

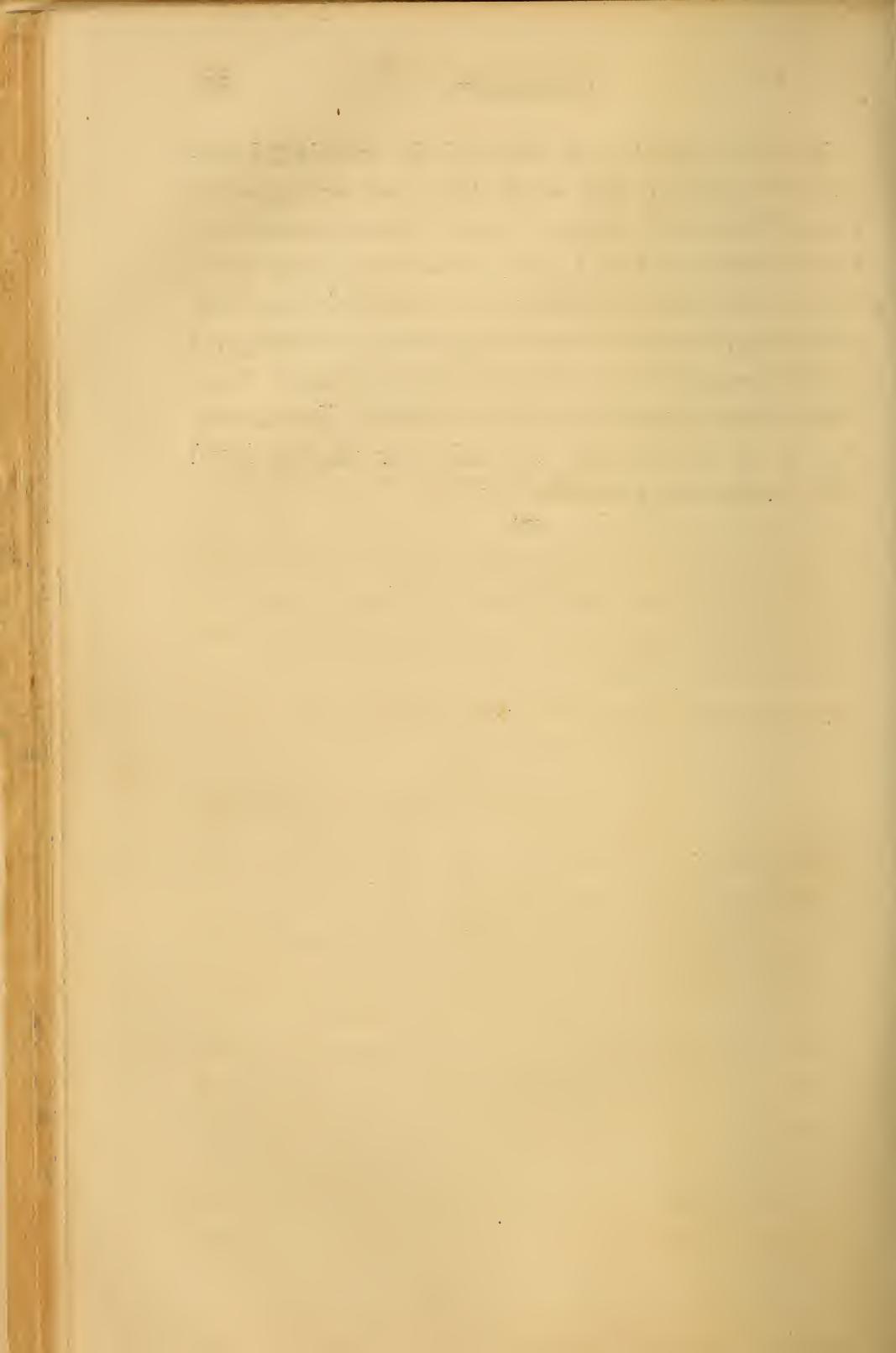
potatoes, cabbage, corn, etc., we have eaten, as fuel, and to-day reappears as heat and motion.

CHANGES OF MATTER.—Chemical changes are taking place wherever we look—on land or sea. The hard granite crumbles and moulders into dust. The stout oak takes in the air and solidifies it; takes up the earth and vitalizes it; changes all into its own structure, and proudly stands monarch of the forest. But in time its leaves turn yellow and sere, its branches crumble, itself totters, falls, and disappears. Our own bodies seem to us comparatively stable, but, with the rock and the oak, they too pass away. All Nature is a torrent of ceaseless change. We are but parts of a grand system, and the elements we use are not our own. The water we drink and the food we eat to-day may have been used a thousand times before, and that by the vilest beggar or the dirtiest earth-worm. In Nature all is common, and no use is base. She keeps no selected elements done up in gilt papers for sensitive people. Those particles of matter we so fondly call our own, and decorate so carefully, a few months hence may have dragged boats on the canal, or waved in the meadow as grass or corn. From us they will pass on their ceaseless round to develop other forms of vegetation and life, whereby the same atom may freeze on arctic snows, bleach on torrid plains, be beauty in the poet's brain, strength in the blacksmith's arm, or beef on the butcher's block. Hamlet must have been somewhat more of a chemist than a madman

when he gravely assured the king that "man may fish with the worm that hath eat of a king, and eat of the fish that hath fed of the worm." Life and death are thus, throughout Nature, commensurate with and companions of each other. Oxygen is the destroyer. It tears down every living structure, and would bring all things to rest in ashes. The sunbeam is its antagonist. It rebuilds and reinvigorates.

THE SUN THE SOURCE OF POWER.—The sun warms, enlivens, and animates the earth. In the laboratory of the leaf it works the most wonderful chemical changes. We see its handiwork in the building of the forest, the carpeting of the meadow, and the tinting of the rose. On the ladder of the sunbeam water climbs to the sky, and falls again as rain. The very thunder of Niagara is but the sudden unbending of the spring that was first coiled by the sun in the evaporation from the ocean. Up to the sun, then, we trace all the hidden manifestations of power. Yet the force that produces such intricate and wide-extended changes is but one twenty-three hundred millionth part of the tide that flows in every direction from this great central orb. But what is our sun itself save a twinkling star beside great suns like Sirius, and Regulus, and Procyon, whose brilliancy in the far-off regions of space drowns our little sun as the dazzling light of day does the smouldering blaze of some wandering hunter?

Thus have we traced some of the wonderful processes by which this world has been arranged to supply the varied wants of man. Wherever we have turned, we have found proofs of a Divine care planning, conforming, and directing to one universal end, while from the commonest things and by the simplest means the grandest results have been attained. Thus does Nature attest the sublime truth of Revelation, that in all, and through all, and over all, the Lord God omnipotent reigneth.



APPENDIX.

PROBLEMS.

MATHEMATICS OF CHEMISTRY.—In solving the problems given on the 17th page, some may prefer to use proportion. The following will suggest the method:

The equivalent of the given constituent : equivalent of the compound :: weight of the constituent : weight of the compound.

Problem 1. How many lbs. of HO are there in a cwt. of $\text{SO}_3 \cdot 2\text{HO}$?

Solution—

$2\text{HO} = 18$ = equivalent of the given constituent.

$\text{SO}_3 \cdot 2\text{HO} = 58$ = equivalent of the compound.

x = weight of the constituent.

100 lbs. = weight of the compound.

$18 : 58 :: x : 100$ lbs.

$$x = 31\frac{1}{9} \text{ lbs.}$$

Prob. 2. How much sodium is there in 20 gr. of sal-soda (NaO.CO_2)?

Solution—

$\text{Na} = 23$ = equivalent of the given constituent.

$\text{NaO} = 31$ = equivalent of the compound.

x = weight of the constituent.

20 gr. = weight of the compound.

$$23 : 31 :: x : 20 \text{ gr.}$$

$$x = 14\frac{2}{3}\text{ gr.}$$

Prob. 3. How much carbonate of lime can be formed from one drachm of C?

Solution—

$\text{C} = 6$ = equivalent of the given constituent.

$\text{CaO.CO}_2 = 50$ = “ “ “ compound.

1 dr. = weight of the given constituent.

x = weight of the compound.

$$6 : 50 :: 1 \text{ dr.} : x.$$

$$x = 8\frac{1}{3} \text{ drachms.}$$

Prob. 4. How much CO_2 would be required to neutralize 2 lbs. of potash?

Solution.—First we find how much KO.CO_2 , two lbs. of KO will make, and then how much CO_2 will be contained in that amount of the salt.

(1.) $\text{KO} = 47$ = equivalent of the constituent.

$\text{KO.CO}_2 = 69$ = equivalent of the compound.

2 lbs. = weight of the constituent.

x = weight of the compound.

$$47 : 69 :: 2 \text{ lbs.} : x = 2\frac{4}{7} \text{ lbs.} = \text{weight of } \text{KO.CO}_2.$$

(2.) $\text{CO}_2 = 22$ = equivalent of the constituent.

KO.CO_2^* = 69 = equivalent of the compound.

x = weight of the constituent.

$2\frac{4}{7}$ = weight of the compound.

$22 : 69 :: x : 2\frac{4}{7}$ lbs.

The remaining problems can be used throughout the term at the discretion of the teacher, whenever the appropriate subject is under consideration in the class.

Prob. 5. What weight of O is contained in 60 gr. of KO.ClO_5 ?

Prob. 6. How much KCl will be formed in preparing 80 gr. of O?

Prob. 7. How much H can be made from 10 lbs. of Zn?

Prob. 8. How much H can be made from 50 lbs. of water?

Prob. 9. How much saltpetre will be required to make 18 lbs. of aquafortis?

Prob. 10. How much oil of vitriol will be required to decompose 6 lbs. of saltpetre?

Prob. 11. How much HO will be decomposed by one drachm of K, and how much KO will be formed?

Prob. 12. What weight of nitrous oxyd will be formed from the decomposition of 6 oz. of nitrate of ammonia?

Prob. 13. How much sal-ammoniac would be required to make 2 lbs. of NH_3 ?

* Some late authorities give the equivalent of K as 39.2, which would slightly change this result.

Prob. 14. How much CO_2 will be formed in the combustion of 30 gr. of CO?

Prob. 15. What weight of carbonate of soda would be required to evolve 12 lbs. of CO_2 ?

Prob. 16. What weight of bicarbonate of soda ($\text{NaO} \cdot 2\text{CO}_2$, "soda") would evolve 12 lbs. of CO_2 ?

Prob. 17. What weight of C is there in a ton of CO_2 ?

Prob. 18. How much O is consumed in burning a ton of C?

Prob. 19. In burning a charge of 10 lbs. of gunpowder, find the weight of the several products formed.

Prob. 20. What weight of common salt would be required to form 25 lbs. of muriatic acid (HCl)?

Prob. 21. HCl of a specific gravity of 1.2 contains about 40 per cent. of the acid. This is very strong commercial acid. What weight of this acid could be formed by the HCl acid gas produced in the reaction named in the preceding problem?

Prob. 22. What weight of hydriodic acid (HI) is formed from a drachm of iodine?

Prob. 23. What weight of Glauber salts can be formed from 100 lbs. of oil of vitriol?

Prob. 24. What weight of S is there in 10 gr. of sulphide of hydrogen?

Prob. 25. How much O is required to change a lb. of SO_2 to SO_3 ?

Prob. 26. How much phosphorus in 40 lbs. of phosphate of lime?

Prob. 27. How much P in 40 lbs. of the superphosphate of lime?

Prob. 28. How much phosphate of lime will an oz. of P make?

Prob. 29. How many lbs. of HO in 186 lbs. of $\text{SO}_3 \cdot 3\text{HO}$?

Prob. 30. How much CO_2 is formed in the combustion of one ton of C?

Prob. 31. What weight of S is there in a ton of iron pyrites?

Prob. 32. What weight of copperas could be made from 500 lbs. of iron pyrites?

Prob. 33. What weight of H is there in a pound of heavy carburetted hydrogen?

Prob. 34. How much O would be required to oxydize the metallic copper which could be reduced from its oxyd by passing over it, when white-hot, 20 gr. of H gas?

Prob. 35. How much O would be required to oxydize the metallic iron which could be reduced in the same manner by 10 gr. of H gas?

Prob. 36. What weight of N is there in 10 lbs. of $\text{NH}_3 \cdot \text{HO}$?

Prob. 37. How much $\text{KO} \cdot \text{ClO}_5$ would be required to evolve sufficient O to burn the H produced by the decomposition of 2 lbs. of HO?

Prob. 38. How much H must be burned to produce a ton of water?

Prob. 39. How much S is there in a lb. of SO_2 ?

THE ALKALIES.

Problem 40. As soda is used so extensively in the arts, it is of great importance to all consumers of soap, glass, etc., that it should be manufactured as cheaply as possible. Leblanc's process of making it from common salt is now universally adopted. The operation comprises two stages: (1) Changing common salt into sulphate of soda; and (2), the changing of this sulphate of soda into carbonate of soda.

The first operation is performed in large cast-iron pans, about 12 inches deep at the centre, and 9 feet diameter. A charge of 500 lbs. of salt is thrown into one of these pans with about an equal weight of SO_3 , and heated. The sulphate of soda is formed with an evolution of HCl fumes. These fumes are conducted into the bottom of a vertical flue, filled with pieces of coke, wet with constantly dripping water. This HO absorbs the gas, and forms a very weak *muriatic acid*, in immense quantities.

The second stage consists in grinding the Glauber salts (sulphate of soda) with an equal weight of chalk ($\text{CaO} \cdot \text{CO}_2$), and half its weight of coal. This mixture is heated and stirred until well melted, when it is raked out to cool. This mass is called "*black ash*." The chemical change that has taken place is very simple; the charcoal deoxydized the salts, changing the sulphate of soda into the sulphuret of sodium. The sulphuret of sodium then reacted with

the carbonate of lime forming the sulphuret of calcium and the carbonate of soda, as follows :



The carbonate of soda alone being soluble in HO, is dissolved out of the black ash, and then crystallized, producing the soda-ash of commerce.

The muriatic acid, which is an incidental product of the first stage, is used in making chloride of lime, so extensively employed in bleaching. The sulphuret of sodium has always been a waste product ; but at the late exposition at Paris (1867), blocks of sulphur, of tons weight each, were exhibited, which had been extracted from it by a process not yet divulged. It is said that 200,000 tons of common salt are annually used in the alkali manufactories of England.

Find how much "soda" is formed from 500 lbs. of salt.

Prob. 41. Find the amount of Glauber salts produced in the first step, with the charge just named.

Prob. 42. Find the amount of HCl produced.

Prob. 43. Find how much sulphuret of sodium is formed in the second step.

Prob. 44. Find how much sulphuret of calcium is made.

Prob. 45. Find how much sulphur could be saved (if none were lost) from the CaS.

Prob. 46. How many lbs. of HCl would be required to neutralize sufficient carbonate of ammonia to form a 30 lb. cake of sal-ammoniac ($\text{NH}_4 \cdot \text{Cl}$) ?

Prob. 47. How much S is there in a ton of plaster (gypsum)?

Prob. 48. How much aluminum is there in a ton of clay?

Prob. 49. How much K is there in 10 lbs. of alum?

Prob. 50. How much white-lead ($\text{PbO} \cdot \text{CO}_2$) could be made from a lb. of litharge?

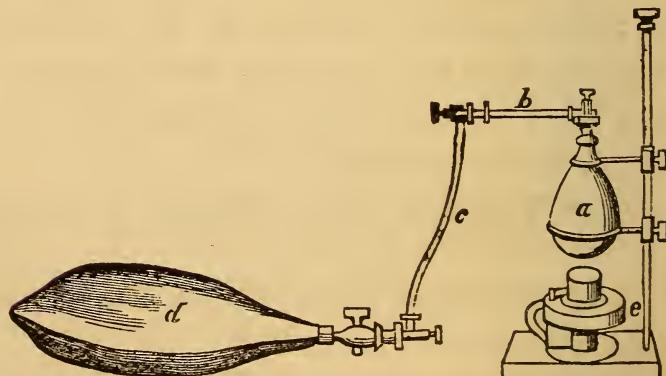
Prob. 51. How many lbs. of C would be required to reduce 40 tons of brown Hematite ($2\text{Fe}_2\text{O}_3 \cdot 3\text{HO}$)?

Prob. 52. In 60 lbs. of heavy spar (sulphate of baryta) how much S is there?

Prob. 53. How much alum can be made from 1 cwt. of potash?

THE METALLOIDS.

(Page 18.) OXYGEN.—In making this gas, a copper flask and rubber tubing should be used, as it is by far the cheapest apparatus. Great care should be



a Copper retort.

b A copper tube leading from it.

c Tube of india-rubber to convey the gas to a gas-bag, gasometer, or pneumatic trough.

d Gas-bag.

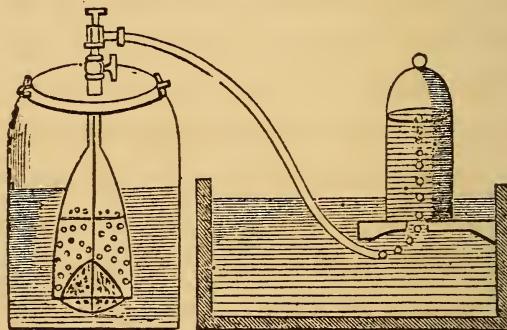
e Spirit-lamp.

taken in pulverizing the KO, ClO₅, as a pressure of more than 10 lbs. is liable to produce an explosion. For the experiments with the watch-spring, phosphorus, etc., common "specie jars" will be found very convenient, or, in necessity, any wide-mouthed bottles which can be obtained of a druggist.—The author will be pleased to correspond with any teacher who may be desirous of information concerning the apparatus which is needed, and the simplest method of performing the various experiments. Priced lists of apparatus, chemicals, etc., can be obtained, on application, from Messrs. J. Nellegar & Co. (late Messrs. Dexter & Nellegar), Albany, N. Y.

(Page 34.) NITROUS OXYD.—A special apparatus is necessary both for preparing and inhaling this gas safely. This consists of a glass retort—as shown in the cut—a wash-bottle, and in addition a gas-bag of from 20 to 50 gallons. capacity for storing the gas, and a smaller bag of from 3 to 5 gallons., with a wide, wooden mouth-piece for inhalation. It is well to pass the gas through a large wash-bottle, as shown in the cut on page 41, *half full of HO*, thence by a rubber tube directly into the large gas-bag. Before making the gas, pour into the bag a couple of gallons of HO: by standing in the bag over this the gas will be purified in a few hours. When about to administer the gas, let the subject grasp his nose firmly between his thumb and forefinger: then, inserting the wooden mouth-piece, be careful that he does not inhale any of the external air, but takes full, deep

breaths in and out of the gas-bag. Watch the eye of the subject, and notice the influence of the gas. Commonly, the best effect is not reached until he begins to surge backward and forward.

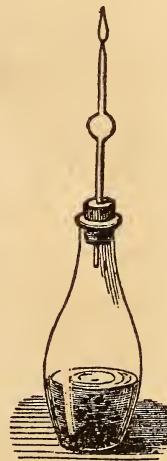
(Page 43.) The zinc for making hydrogen should be granulated. This is easily effected by pouring the melted metal slowly from the ladle into a basin of HO. A common junk-bottle, fitted with a cork and a glass tube, will answer for the evolution of the gas, but a "hydrogen generator," as sold by apparatus dealers, is much more satisfactory. In experi-



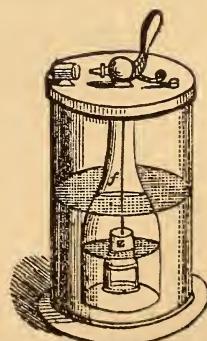
Hydrogen Generator.

menting with H, great care must be used not to ignite the jet of gas until all the common air has passed out of the flask; otherwise a severe explosion will ensue. It is a safe precaution to test the gas by passing it in bubbles up through HO, and igniting them at the surface; the force of the combustion will indicate if there be any danger. It must not be kept for any great length of time in bags, as the air will gradually force itself in, and the gas will

partly pass out by the law of diffusion, thus forming a mixture which it is dangerous to ignite. The adjoining illustration of a jet of burning H is a representation of what is called "The Philosopher's Lamp." In using the "mixed gases," the utmost care is requisite. The gases may be passed into a gas-bag, made of a common bladder, furnished with a stop-cock. A clay tobacco pipe may be attached to it by means of a bit of rubber tubing. A plate of good soapsuds makes the outfit complete. Blow the bubbles with the gases in the bag, either in the air, or on the tin plate, but be cautious not to ignite them until the stop-cock is turned, and the bag withdrawn from the dish. Pure H bubbles may be blown in the same manner: if out of doors, they will float off to a great distance. H may be better purified for inhaling, by passing it through a solution of potash, with some alcohol added to it. The action of platinum sponge is best shown by the instrument represented in the cut. It was formerly used by chemists as a convenient way of obtaining a light in the laboratory. Friction matches have superseded such clumsy inventions. The experiments with the compound blowpipe, as shown in the frontispiece, Dobereiner's Lamp.



The Philoso-
pher's Lamp.



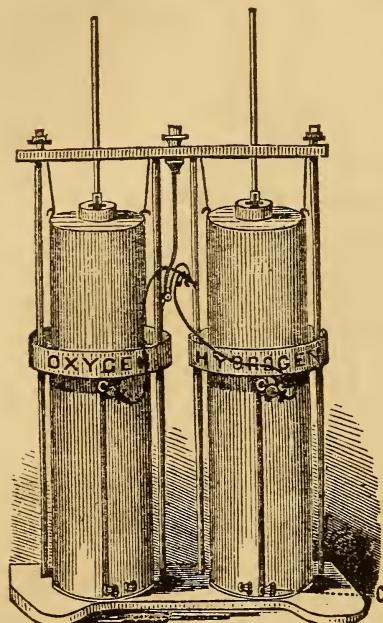
can be given either by the use of gasometers, or, in their stead, rubber gas-bags may be substituted at a

much lower price. The H gun—which is simply a tin tube, closed at one end, and provided with a cork at the other, having a priming-hole at the side—may be filled over the Philosopher's Lamp when not ignited. The gas is allowed to pass in until the gun is about a fifth full, as nearly as one can guess.

Some teachers will prefer to use the more exact chemical term “molecule,” when speaking of a com-

ound, to the word “atom,” as employed in the text. *Molecule means the smallest quantity of a compound that can exist by itself.* Thus the exact language of such would be—“An atom of H and one of O unite, and form a molecule of HO.” This term can be substituted very easily by those who desire it. The author has not employed it, lest he might confuse some beginners by an unnecessary scientific term.

(Page 47.) WATER is analyzed by the action of the galvanic current in the manner shown in the following cut. We analyze it when we put upon our coal



Gasometer.

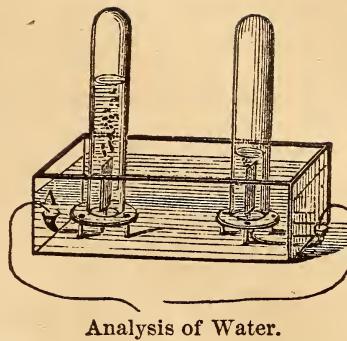
fire cinders wet with HO. The HO adds to the intensity of the fire, and "makes it burn better," as we say.

(Page 55.) THE DIAMOND.—Although the diamond is simply pure carbon, yet it has never been made

by any chemical process. Minute diamonds, it is said, have been separated from carbon compounds by long-continued voltaic action, but they were invisible except by a microscope. The value of the diamond varies with the market; the *general* rule is as follows: a gem ready for setting, of one carat weight, is worth \$40 to \$60; beyond this size, its value increases according to the square of its weight. The *Kohinoor* (mountain of light) weighs 103 carats, and is valued at \$10,000,000.

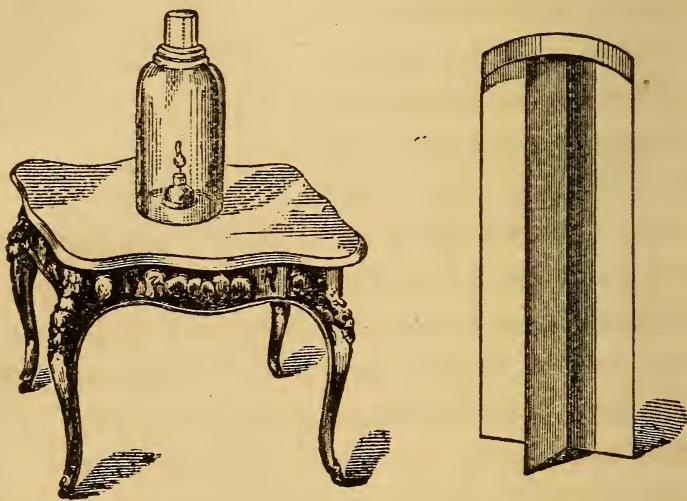
(Page 64.) CARBONIC ACID.—The experiments with this gas may be still further varied by having at the bottom of the inclined plane shown in the cut on page 65, a light model of a water-wheel. The invisible gas flowing down-hill will turn it very freely, especially if too many candles are not burning at the time.

Ventilation is thought by many to be perfectly provided for if there be a ventilator placed at the top of the room, presenting one small opening for the egress of the bad air. To show the fallacy of this, we need only perform the experiment represented in



Analysis of Water.

the adjoining cut. The bottle is fitted with a tin cover, through which a tube is inserted. The jar represents a room sealed tightly on all sides against



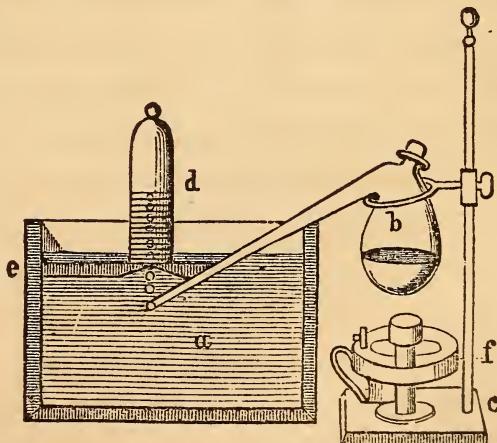
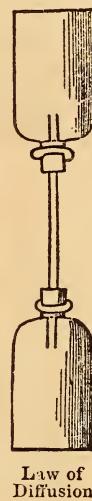
the incoming of the air, and with only one opening for ventilation. Place a lighted candle at the bottom, and it will soon be extinguished, no O seeming to come in to feed the flame. Place now in the tube a slide, composed of two slips of tin soldered at right angles to each other, thus dividing the tube into four longitudinal portions. The lighted candle will burn freely, and a bit of smoking paper held at the top of the tube will reveal a current passing downward through two of the openings, and a current passing outward through the opposite ones. This shows very clearly the effect of a division in the opening used for ventilation. Of course, no room can be made as nearly air-tight as the bottle, since some air will come in at the sides, around the win-

dows, etc.; still, this experiment illustrates the imperfection of the ordinary ventilator. The necessity of some means of changing the air is shown by the fact, that two persons sleeping in a room 15 ft. square will vitiate the atmosphere in three hours, and so rebreathe it twice before morning, and then wonder why they wake up with a headache.

(Page 73.) CYANOGEN.—The pupil will here distinguish ferrocyanide of potassium from the ferricyanide. The latter is the *red prussiate of potash*. When the yellow prussiate is added to a salt of the sesquioxyd of iron, *prussian blue* is formed. This is employed in water-colors and oil-paintings, and when dissolved in oxalic acid, constitutes *blue ink*.

(Page 83.) THE LAW OF DIFFUSION may be finely illustrated by the experiment shown in the cut. The upper jar is to be filled with H, and the lower one with CO₂. The result will be that described in the text.

(Page 86.) CHLORINE.—In the arts, and for many experiments, Cl is made by simply



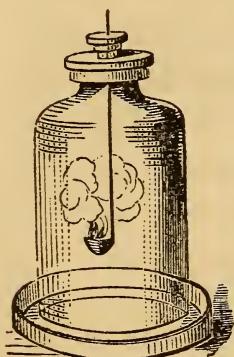
a Pneumatic trough. d Bell glass receiver.
b Retort. e Shelf in pneumatic trough.
c Lamp-stand. f Spirit-lamp.

heating, in a glass retort, black oxyd of manganese, with muriatic acid. The reaction is this :



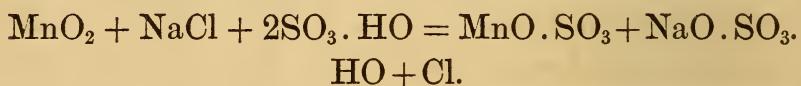
Indeed, most of the experiments in Cl may be performed by taking a deep glass jar, and placing at the bottom some chloride of lime. By pouring upon this a little dilute SO_3 , the Cl will soon fill the jar and dis-

place the air. Phosphorus will inflame spontaneously in Cl. The gas is very annoying, and the room must be thoroughly ventilated.



Phosphorus in Cl.

In preparing Cl, as mentioned in the text, take four parts of common salt and mix it thoroughly with three parts of black oxyd of manganese; put this mixture in the retort, and pour upon it dilute SO_3 . The gas will be evolved abundantly. The reaction is as follows :



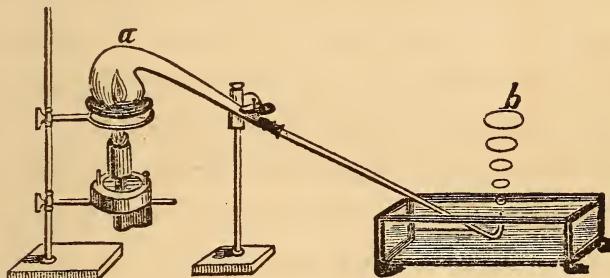
The gas should be collected over warm water, as it is largely absorbed by cold water. By passing the gas for some time through a bottle of HO, a solution will be formed which will perform all the experiments in bleaching very nicely. To illustrate this, pour some of the chlorine-water into a test-tube of HO blackened with a few drops of ink.

(Page 88.) BLEACHING POWDER is considered to be a mixture of the chloride of calcium and the

hypochlorite of lime—thus, $\text{CaCl} + \text{CaO}\cdot\text{ClO}$. It is produced in great quantities in the process of making sal-soda.

(Page 93.) BIBORATE OF SODA ($\text{NaO}\cdot2\text{BO}_3 + 10\text{HO}$) is used in soldering and in brazing, and also in “blow-pipe analysis.” When borax is melted with oxyd of chromium, it gives an emerald green; with oxyd of cobalt, a deep blue; with oxyd of copper, a pale green; with oxyd of manganese, a violet.

(Page 103.) PHOSPHIDE OF HYDROGEN is frequently made by nearly filling a retort with a strong solution



a Retort filled with solution of potash, with pieces of phosphorus in it.
b Rings of vapor, from the combustion of the phosphuretted hydrogen.

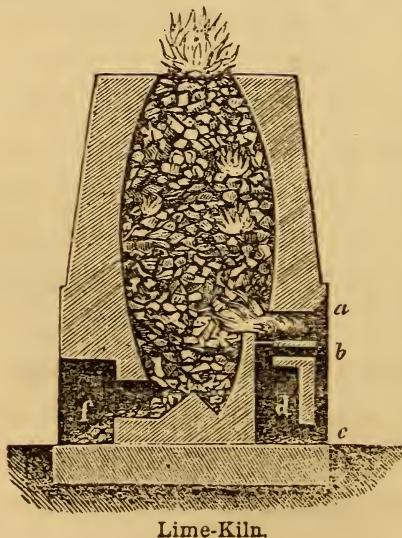
of KO, and then adding a few drops of ether and some small bits of phosphorus. The object of the ether is to prevent the explosion of the first bubbles of gas, as they come off, in the retort. The beak of the retort should dip under HO before applying the heat.

The following singular story is told of the probable discovery of phosphorus many years before that of Brandt, the reputed discoverer. A certain prince San Severo, at Naples, exposed some human

skulls to the action of several reagents, and then to the heat of a furnace. From the product he obtained a vapor which kindled at the approach of a light, and continued to burn aglow for months without apparently diminishing in weight. San Severo refused to divulge the process, as he wished his family vault to be the only one to possess a "*perpetual lamp*," the secret of which he considered himself to have discovered.

(Page 110.) SAL-SODA is sometimes called "salts of tartar," and when purified is commonly sold under that name. It is used by barbers for cleaning the head, and is a prominent constituent in many hair-washes; 20 or 30 gr. in a gill of warm HO makes an excellent solution for such a purpose.

(Page 115.) METALS OF THE ALKALINE EARTHS.—These are termed alkaline because they are caustic, and earths, because they are insoluble in HO. The

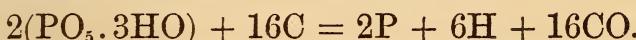


annexed cut shows an improved form of lime-kiln, in which the process is continuous. At *a*, *b*, *c*, *d*, are the doors for fuel, ash-pit, etc. The lime-stone is fed at the top from time to time, while the lime is taken out at *f* as fast as formed.

Concrete is a cement of coarse gravel and water-

lime. It is of great durability. *Whitewash* is a mere "milk of lime." "*Hard finish*" is a kind of plaster in which gypsum is used to make the wall smooth and hard. "*Calcimining*" is a process of whitening walls with a wash of plaster of paris, or whiting.

(Page 119.) **PHOSPHATE OF LIME.**—When bones are burned, a tribasic phosphate of lime is formed—thus, $3\text{CaO} \cdot \text{PO}_5$. When this is heated with SO_3 , the change is as follows: $3\text{CaO} \cdot \text{PO}_5 + 2(\text{SO}_3 \cdot \text{HO}) = \text{CaO} \cdot \text{PO}_5 \cdot 2\text{HO} + 2(\text{CaO} \cdot \text{SO}_3)$. This mixture is sometimes called the superphosphate of lime, although the term belongs properly only to the $\text{CaO} \cdot \text{PO}_5$. By filtering, the $\text{CaO} \cdot \text{SO}_3$ is removed, and the superphosphate is sold as a fertilizer, or may be heated with charcoal to form P—thus:



(Page 129.) When iron is cast in large masses, the metal has time to crystallize, and this weakens it very much. When immense cannon are cast, like the Fort Pitt gun, a stream of water is allowed to run through it to hasten the cooling process. When the melted iron is cooled in an iron mould, this chills the surface instantly, and makes it extremely hard. The product is called "*chilled iron*," and is used for safes and other burglar-proof instruments.

(Page 133.) **COPPER.**—Both lead and copper are frequently found native, the former in Missouri and Northern New York; the latter near Lake Superior. In such cases, the extraction of the metal from the spar in which it is imbedded is very simple. The ore is

ground to powder in a stamp-mill, and then, by repeated washing, during which the metal sinks by its superior specific gravity, is separated from the spar, and is prepared for the furnace, where it is melted and cast into bars for the market. The ore, containing oxyd, or carbonate of copper, can readily be reduced by heating with charcoal and lime, as in the process of iron-smelting. The sulphurets, however, are reduced with much greater difficulty. They contain much iron pyrites, which must be removed. They are first roasted, to convert a part of the sulphurets of copper and iron into oxyds. They are then smelted, as we have described before, and the iron mostly passes off in the slag, while the copper is reconverted into a sulphuret. This is next roasted, and lastly heated to so high a temperature, that the sulphur leaves the copper as SO_2 , while the melted metal is drawn off, ready for the market.

(Page 138.) COBALT is a reddish-white metal, found in combination with arsenic. It received the name *cobalus* from the miners, because its ore looked so bright that they thought they would obtain something valuable, but by roasting, it crumbled to ashes. They therefore thought they were mocked by the Kobolds—the evil spirits of the mines. The oxyd of cobalt makes a beautiful blue glass, which, when ground fine, is called *smalt*. It is used for tinting paper, and by laundry women to give the finished look to cambrics, linen, etc. Its impure oxyd, called *zoffer*, imparts the blue color to common earthenware and

porcelain. The chloride (CoCl) is used as a sympathetic ink. Letters written with a dilute solution of it are invisible when moist with the HO absorbed from the air, but on being dried at the stove, again become blue. If the paper be laid aside the writing disappears, but may be revived in the same manner. A winter landscape may be drawn with india-ink, the leaves being added with this ink. On being brought to the fire it will bloom into the foliage of summer.

MANGANESE is a hard, brittle metal, resembling cast-iron in its color and texture. It takes a beautiful polish. Its binoxyd, the black oxyd of manganese, has been spoken of as used in the manufacture of O , Cl , etc. By fusing four parts of MnO_2 and three and a half parts of chlorate of potash with five parts of KO dissolved in a little water, a dark green mass is obtained called "*chameleon mineral*." If a piece of this be dropped into HO , the solution will undergo a beautiful change from green, through various shades, to purple. This is owing to the gradual formation of permanganic acid. The change may be produced instantaneously by a drop of SO_3 .

NICKEL is a grayish metal. Like cobalt, it is a constituent of meteorites. It is mined in Pennsylvania, in large quantities, by the United States Government, for making nickel cents. Its principal use is in the alloy called German silver. The salts of nickel possess a beautiful green tint. The rare gem chrysoprase is colored with oxyd of nickel.

BISMUTH is a reddish-white metal. It is known

chiefly as an oxyd, in which form it is much prized as a cosmetic by those whose fading charms necessitate the use of pearl-powder. This should not be indulged in by ladies intending to visit chemical laboratories, or lectures, as a few bubbles of HS escaping into the air will change the snow-white complexion into a most suggestive black.

ANTIMONY was discovered by Basil Valentine, a monk of Germany, in the fifteenth century. It is said, that to test its properties, he first fed it to some hogs kept at the convent, and found that they thrived upon it. He then tried it upon his fellow-monks, but perceiving that they died in consequence, he forthwith named the new metal, in honor of this fact, *anti-moine* (anti-monk), whence our term *antimony* is derived.

Antimony is found as SbO_3 . It is a brittle bluish-white metal, with a beautiful laminated crystalline structure. It is used simply as an alloy for type-metal, Britannia-ware, etc. Its test is HS, which throws down a brilliant orange-colored precipitate. Example : Melt a small fragment before the blow-pipe, and throw the melted globule upon an inclined plane. It will instantly dart off in minute spheres, each leaving behind a long trail of smoke.

(Page 149.) NITRATE OF SILVER is much used in photography. An account of the processes pursued in this art may be interesting to some. The daguerreotype is named from M. Daguerre, the dis-

coverer, who received a pension of 6,000 francs per year from the French government. A plate of copper, plated on one side with silver, is exposed to the vapor of iodine until a compound of iodide of silver is formed upon the surface. This is extremely sensitive to the light, and for this reason the process is always conducted in a dark closet. The plate is then quickly carried, carefully covered, to the camera, and placed in the focus, where the rays of light from the person whose "picture is being taken" fall directly upon it. These rays decompose the iodide of silver, setting free the iodine. The amount of this change is directly proportional to the number of rays that are reflected from different parts of the person to form the image in the camera. A white garment reflects all the light that falls upon it, so that part of the plate corresponding will be very much changed. A black garment reflects no light, so that part will not be changed at all. The different colors and shades reflect varying proportions of light, and so influence the plate correspondingly. When the plate is taken out of the camera, it is carefully covered again and carried quickly into the dark closet. No change can be detected by the eye; but now expose it to the vapor of mercury, and wherever the silver has been freed from the iodine, the Hg combines with it, forming a whitish amalgam. The picture thus evoked comes forth nearly perfect in its lights and shades, but the whole side

of the plate is covered with the iodide of silver, which would blacken if we should carry it out into the light. This must, therefore, be removed, so we wash the plate with *hyposulphite* of soda (NaO.SO_2). This dissolves the iodide of silver, except where it has been fixed by the mercury, and our picture needs only washing and a little paint on the lips and cheeks to be finished. If, instead of iodine, we had used bromine, the bromide of silver thus formed would have been much more sensitive to the light, and the picture could have been taken much quicker.

PHOTOGRAPHY (light-drawing) is founded essentially upon the same principles as daguerreotyping. The process varies so much with different operators that only the general outlines can be given. The details depend upon the quickness, exactness, and skill of the artist so much, that the same materials in different galleries produce vastly different photographs. So much skill has been attained in this art, that instantaneous views are now taken by Anthony & Co., of New York. In their gallery the camera tube is closed by a slide which is drawn to its place by a heavy weight. The camera is "focused," for instance, upon a regiment of soldiers moving up Broadway, and the tube opens just as they are raising their feet for a step: before they place them on the ground the slide falls and the picture is taken—they are photographed all standing on one foot, and with the other in the air. The process is as follows: The glass plate is (1) thoroughly cleansed; (2) a small

quantity of iodized collodion * is poured upon it, which covers the glass with a thin transparent film, when (3) it is put in the "nitrate of silver bath," † where the salt of silver in the bath is absorbed by the collodion film and changed to iodide of silver. The plate is now ready for the picture. After the sitting the plate is (4) taken, carefully protected from the light, to the operator's room. Here the picture is (5) *developed* by a solution of protosulphate of iron, with a little acetic acid added. (6) It is washed thoroughly; (7) it is *fixed* with a solution of hyposulphite of soda; (8) it is washed and dried, and (9) coated with amber varnish to preserve the film from accidental injury. This completes the "*negative*." From this the pictures are (1) "printed" by placing the negative upon a sheet of prepared paper,‡ and exposing it to the sun's rays. The lights and shades are now reversed, and when the colors are sufficiently deepened the picture is (2) *washed*, (3) *toned* in the "toning-bath," which contains chloride of gold, and imparts the delicate color to the photograph, (4) *washed*, (5) *fixed*, by

* Iodized collodion is composed of gun-cotton dissolved in alcohol and ether, iodized with iodide of ammonium and bromide of cadmium.

† The nitrate of silver bath contains nitrate of silver, iodide of silver, and water.

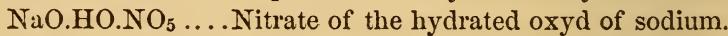
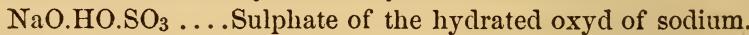
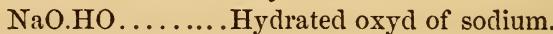
‡ The paper is "sensitized" by immersing it in a solution of chloride of sodium, and then in one of nitrate of silver, thus filling the pores of the paper with the chloride of silver, which is extremely sensitive to light.

placing the paper in hyposulphite of soda, (6) *washed*, (7) *dried*, and (8) mounted on card-board, which completes the picture.

ORGANIC CHEMISTRY.

All organic substances contain carbon, and therefore they have been defined as the "carbon compounds." The phenomena of Allotropism and Isomerism are evidence that the grouping of a compound has much to do with its peculiar properties. The recent advances of the science have developed several features worthy the attention of the student.

A RADICAL is the base of a system of compounds. Example : Na forms, by union with O, the oxyd of sodium. This combines with HO, forming the hydrated oxyd of sodium, and this again with various acids. In this way a regular series of compounds are produced, in which Na is the starting point—the root, as it were. Thus :



A COMPOUND RADICAL is a compound that resembles an element in all its chemical behavior, and can be oxydized and transferred from one compound to another, forming chlorides, salts, etc., in the same manner as a metal, like copper or iron. Example : In the destructive distillation of $\text{C}_4\text{H}_6\text{O}_2$ (alcohol)

and SO_3 , the acid takes out an atom of HO , leaving $\text{C}_4\text{H}_5\text{O}$ —common sulphuric ether. Now, by taking an atom of O from this, there remains a colorless gas, C_4H_5 , which has received the name Ethyl and the symbol Ae. This plays the part of an element, and being composed of two elements, is called a compound radical. It is the root of a series of compounds, thus :

Ae—Ethyl (the radical).....	C_4H_5 .
AeO—Oxyd of ethyl (ether).....	$\text{C}_4\text{H}_5\text{O}$.
AeO.HO—Hydrated oxyd of ethyl (alcohol).....	$\text{C}_4\text{H}_5\text{O}.\text{HO}$.
AeCl—Hydrochloric ether.....	$\text{C}_4\text{H}_5\text{Cl}$.
AeCy—Cyanide of ethyl.....	$\text{C}_4\text{H}_5\text{Cy}$.
AeNO ₅ —Nitrate of the oxyd of ethyl (nitric ether)....	$\text{C}_4\text{H}_5\text{O}.\text{NO}_5$.

By this we see that ether is the oxyd of ethyl, and may be represented by the symbol AeO, while alcohol is the hydrated oxyd of ethyl, and may be represented by the corresponding symbol AeO.HO.

HOMOLOGOUS bodies are those which differ from each other by the constant addition of C_2H_2 , or its multiple. By the decomposition of common alcohol, we procure a series of alcohols, ethers, and acids, which differ from each other by constantly adding C_2H to the preceding member of the group.

<i>Alcohols.</i>	<i>Acids.</i>	<i>Ethers.</i>
Methylic.... $\text{C}_2\text{H}_4\text{O}_2$	Formic..... $\text{C}_2\text{H}_2\text{O}_4$	Methylic.... $\text{C}_2\text{H}_3\text{O}$
Common.... $\text{C}_4\text{H}_6\text{O}_2$	Acetic $\text{C}_4\text{H}_4\text{O}_4$	Common ... $\text{C}_4\text{H}_5\text{O}$
Propylic ... $\text{C}_6\text{H}_8\text{O}_2$	Propionic ... $\text{C}_6\text{H}_6\text{O}_4$	$\text{C}_6\text{H}_7\text{O}$
Butylic $\text{C}_8\text{H}_{10}\text{O}_2$	Butylic $\text{C}_8\text{H}_8\text{O}_4$	Butylic $\text{C}_8\text{H}_9\text{O}$
Amylic..... $\text{C}_{10}\text{H}_{12}\text{O}_2$	Voleric..... $\text{C}_{10}\text{H}_{10}\text{O}_4$	Amylic $\text{C}_{10}\text{H}_{11}\text{O}$
	$\text{C}_{12}\text{H}_{14}\text{O}_2$	$\text{C}_{12}\text{H}_{13}\text{O}$
	$\text{C}_{14}\text{H}_{16}\text{O}_2$	$\text{C}_{14}\text{H}_{15}\text{O}$
Caprylic $\text{C}_{16}\text{H}_{18}\text{O}_2$	Caprylic $\text{C}_{16}\text{H}_{16}\text{O}_4$	Caprylic $\text{C}_{16}\text{H}_{17}\text{O}$

Many of these various substances are of no practical value as yet, and some, as seen above, are merely hypothetical, but will probably be separated as the others have been, while all will doubtless become of use in the arts. In the art of dyeing they have been utilized, and have revolutionized the entire system. There are other compound radicals—as C_2H_3 , called methyl, symbol Me—whose oxyds form ethers, and hydrated oxyds alcohols, as in the case of Ae.

KAKODYL is a combination of Me with arsenic—thus, $Ae_2 As$ —and is a fearfully poisonous liquid. It takes fire spontaneously in the air, producing CO_2 , and AsO_3 . It has been used for filling bombs, as a most destructive agent of war. The homologous series has been continued up to melissic acid ($C_{60}H_{60}O_4$), and melissic alcohol ($C_{60}H_{62}O_2$). The extremes differ much in their characteristics. Formic acid, which is found in red ants (*formica rufa*), is a fiery pungent acid that blisters the skin, while melissic acid is a solid fat. The compound radical, like any metal or acid, unites directly with Cl, I, H, Zn, S, and forms crystallized salts.

SUBSTITUTION AND REPLACEMENT.—This curious law is stated thus—that “one or more elements of a compound may be replaced by any other element or group of elements which are equivalent in their chemical relations, and the chemical constitution remain unchanged.” (*Silliman.*) For example: 1st. Ammonia (NH_3) may be written thus: $N\frac{H}{H}$. Now we

can substitute for an atom of H a compound radical, as Ae (ethyl), and we have $N\left|\begin{smallmatrix} C_2H_5 \\ H \end{smallmatrix}\right|$, an ethyl-ammonia; or, displace two atoms of H, and we have $N\left|\begin{smallmatrix} C_2H_5 \\ C_2H_5 \\ H \end{smallmatrix}\right|$, a bi-ethyl ammonia; or, substituting three atoms of ethyl, we have $N\left|\begin{smallmatrix} C_2H_5 \\ C_2H_5 \\ C_2H_5 \end{smallmatrix}\right|$, a tri-ethyl ammonia. These three ammonias are called methylamine, bimethylamine, and trimethylamine. They closely resemble ammonia, neutralize acids, precipitate the bases from salts, form white clouds with HCl, as in the test of ammonia, and form crystallizable salts; though they steadily rise in boiling point, ethylamine boiling at 54.4° , and trimethylamine at 195.8° . Other radicals yield other ammonias, similar to ammonia in odor and other properties.

2d. Acetic acid ($C_2H_4O_2$) may be written $C_2\left|\begin{smallmatrix} H \\ H \\ H \end{smallmatrix}\right|O_2$,

and the four atoms of its H may be replaced in succession by three atoms of HCl (hydrochloric acid), and form $C_2\left|\begin{smallmatrix} HCl \\ HCl \\ HCl \end{smallmatrix}\right|O_2$, without at all changing the acid character, and modifying but slightly its properties. This new acid is called chlor-acetic, symbol $C_2(HCl)_3O_2$.

3d. The hydrogen of Ammonia may not only thus be replaced by a compound radical, as ethyle, amyle, etc., but even by two or more radicals, or by chlorine, bromine, iodine, zinc, etc. Thus, tartaric acid ($C_4H_6O_6$) may be written $C_4\left|\begin{smallmatrix} H \\ H \\ H \\ H \end{smallmatrix}\right|O_6$. Now, if we re-

place two of the atoms of H with two atoms of Zn, we have $C_8 \left| \begin{matrix} \text{Zn} \\ \text{H}_4 \end{matrix} \right| O_{12}$, or $C_8 H_4 Zn_2 O_{12}$; or, they can be replaced by one atom of Zn and one of K—thus, $C_8 \left| \begin{matrix} \text{Zn} \\ \text{K} \\ \text{H}_4 \end{matrix} \right| O_{12}$, and the symbol will be $C_8 ZnKH_4 O_{12}$. These various changes indicate what a vast field lies open for discovery in organic chemistry, and the multiplicity of possible compounds. The difficulty of properly classifying them is at present insurmountable.

ALDEHYDE.—Alcohol ($C_4 H_6 O_2$) is changed into acetic acid ($C_4 H_4 O_4$) by taking up two atoms of O from the air to combine with two elements of its H, thus forming two molecules of HO. In this there is an intermediate step, during which the two atoms of H seem to have left the alcohol in their anxiety to combine with O, while the alcohol has not yet taken its O to form the acetic acid. This intermediate substance ($C_4 H_4 O_2$) is called aldehyde. It may be smelt by holding a red-hot coil of platinum wire in a goblet containing a few drops of alcohol.

This experiment, showing the formation of aldehyde from alcohol, may be very profitably followed by another, illustrating the change of alcohol into acetic acid. Place a little platinum black in a watch crystal, near a small cup of alcohol. Cover them both with a glass receiver, and set them in the sunlight. Soon a mist will gather, and tiny streams of the condensed vapor of acetic acid will collect and run down the sides of the glass. Fresh air must be occasionally admitted to oxydize the alcohol.

(Page 199.) The term Morphia is used by those who think the substance an alkali; Morphine, by those who deem it a neutral body.

OPIUM-EATING has become so prevalent in this country that a few remarks upon it may not be unprofitable. The effect is principally upon the nervous system. A delicious reverie steals over the senses. Every avenue of sensation is thrilled with ecstatic enjoyment. The delirious dream becomes a vivid reality. Riches pour in abundantly, and the happy possessor revels in costly mansions with elegant appointments; he wanders in gardens of tropical luxuriance and gorgeousness, where birds of the rarest plumage sport in the branches, music trembles in the air, and perfumes steal the senses. History, poetry, science, art—all the treasures of knowledge are his, and the soul expands to utter the most brilliant thoughts. The grandest schemes present themselves and prompt to the pursuit of most impossible results. Every sense is satisfied, and the whole man is at perfect peace. But, with the effect of the drug, the dream passes off, and then there comes a peculiar longing, an insatiable craving, which demands a repetition of the fascinating stimulus. In the course of time the amount necessary to produce the desired effect becomes increased, until at last, in some cases, an ounce of laudanum, or ninety grains of the acetate of morphia, have been consumed daily. At the first it seems only a gratification of a harmless desire, but insensibly, as

the habit becomes fixed, it develops an ungovernable passion. Step by step the unsuspecting victim is led on, until at last some vain effort at release reveals to him the chains by which he is fast bound to a fascinating but fearful practice. Too often he finds it already too late. The subtle alkaloid has worked its way into the tissues and coatings of his entire internal organism. At first, while combining with the nerves, it set free a vast amount of vitality and force, but now it has satisfied itself. Already the whole system is impregnated with it, and no additional dose produces a thrill even of the delicious rapture for which the drug was once so eagerly sought. If he continues its use, a CERTAIN, FEARFUL, AGONIZING DEATH AWAITS HIM. If, resolutely, he summons his already enfeebled will, and commences the conflict, an agony of endurance, which defies all description, is before him. The whole body must be reorganized, and, atom by atom, the life-energy of the man drag out of the flesh and blood the corrosive poison. For weeks and months he endures the terrible torture, racked by intensest agony in every nerve and fibre, with visions of horror filling the mind. At last, the constitution conquers or the man dies. Yet this fearful struggle is better than apathy, for the victim of this habit moves on directly to one fate—the opium-eater's grave.

This frightful but “o'er true” picture of the opium-

eater's fate should deter all who need it from thoughtlessly using paregoric, laudanum, morphine, or opium, in any form, lest they, too, may come also to such a doom. In almost every case it is taken first as a sedative from pain or fatiguing labor, with no thought of becoming addicted to its use. But so insinuating is it that the victim forms the habit ere he is aware, and only knows he is a slave when for some reason he attempts to cease the customary dose and finds himself bound to a bitter servitude.

CIRCULATION OF MATTER.—The truth that matter passes from the animal back to the vegetable, and from the vegetable to the animal kingdom again, received a curious illustration not long since, as stated in the Hartford Press.* For the purpose of erecting a suitable monument in memory of Roger Williams, the founder of Rhode Island, his private burying-ground was searched for the graves of himself and wife. It was found that everything had passed into oblivion. The shape of the coffins could only be traced by a black line of carbonaceous matter. The rusted hinges and nails, and a round wooden knot, alone remained in one grave ; while a single lock of braided hair was found in the other. Near the graves stood an apple-tree. This had sent down two main roots into the very presence of the confined

* The author has in his possession a letter, from a gentleman who was present at the opening of this grave, attesting the truth of this singular statement.

dead. The larger root, pushing its way to the precise spot occupied by the skull of Roger Williams, had made a turn as if passing around it, and followed the direction of the backbone to the hips. Here it divided into two branches, sending one along each leg to the head, when both turned upward to the toes. One of these roots formed a slight crook at the knee, which made the whole bear a striking resemblance to the human form. There were the graves, but their occupants had disappeared; the bones even had vanished. There stood the thief—the guilty apple-tree—caught in the very act of robbery. The spoliation was complete. The organic matter—the flesh, the bones, of Roger Williams—had passed into an apple-tree. The elements had been absorbed by the roots, transmuted into woody fibre, which could now be burned as fuel, or carved into ornaments; had bloomed into fragrant blossoms, which had delighted the eye of passers-by, and scattered the sweetest perfume of spring; more than that—had been converted into luscious fruit, which, from year to year, had been gathered and eaten. How pertinent, then, is the question, “Who ate Roger Williams?”

Shakespeare expresses the same chemical thought when he says:

“Imperious Cæsar, dead and turned to clay,
Might stop a hole to keep the wind away.
Oh! that the earth which kept the world in awe
Should patch a wall to expel the winter’s flaw!”

Or, again, when he makes Ariel sing :

“ Full fathom five thy father lies :
 Of his bones are coral made ;
Those are pearls that were his eyes ;
 Nothing of him that doth fade
 But doth suffer a sea change
 Into something rich and strange.”

Autumn Gravel
Alumina
Spectral Analysis

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Resolved, That this committee has observed with gratification the efforts made by the editors and publishers of several mathematical works, designed for the use of common-schools and other institutions of learning, to introduce the Metric System of Weights and Measures, as authorized by Congress, into the system of instruction of the youth of the United States, in its various departments; and, in order to extend further the knowledge of its advantages, alike in public education and in general use by the people,

Be it further resolved, That Professor Charles Davies, LL.D., of the State of New York, be requested to confer with superintendents of public instruction, and teachers of schools, and others interested in a reform of the present incongruous system, and, by lectures and addresses, to promote its general introduction and use.

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American schools are at last supplied with an American edition of this famous text-book. Many of our best institutions have for years been procuring it from abroad rather than forego the advantages it offers. The policy of putting students who have acquired some proficiency from the ordinary text-books, into a Grammar written in the vernacular, can not be too highly commended. It affords an opportunity for finish and review at once; while embodying abundant practice of its own rules.

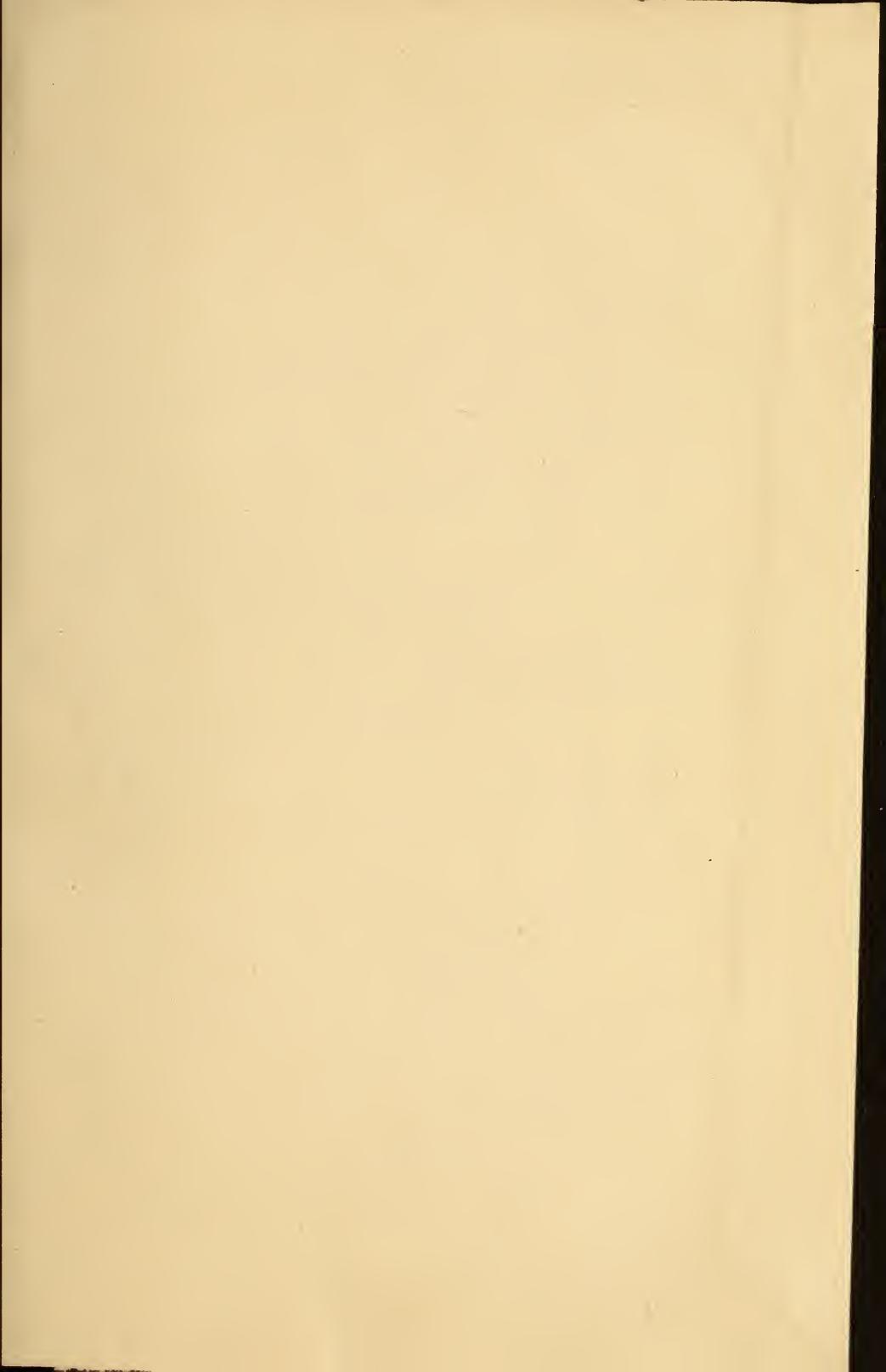
Worman's Elementary German Grammar, . .	1 00
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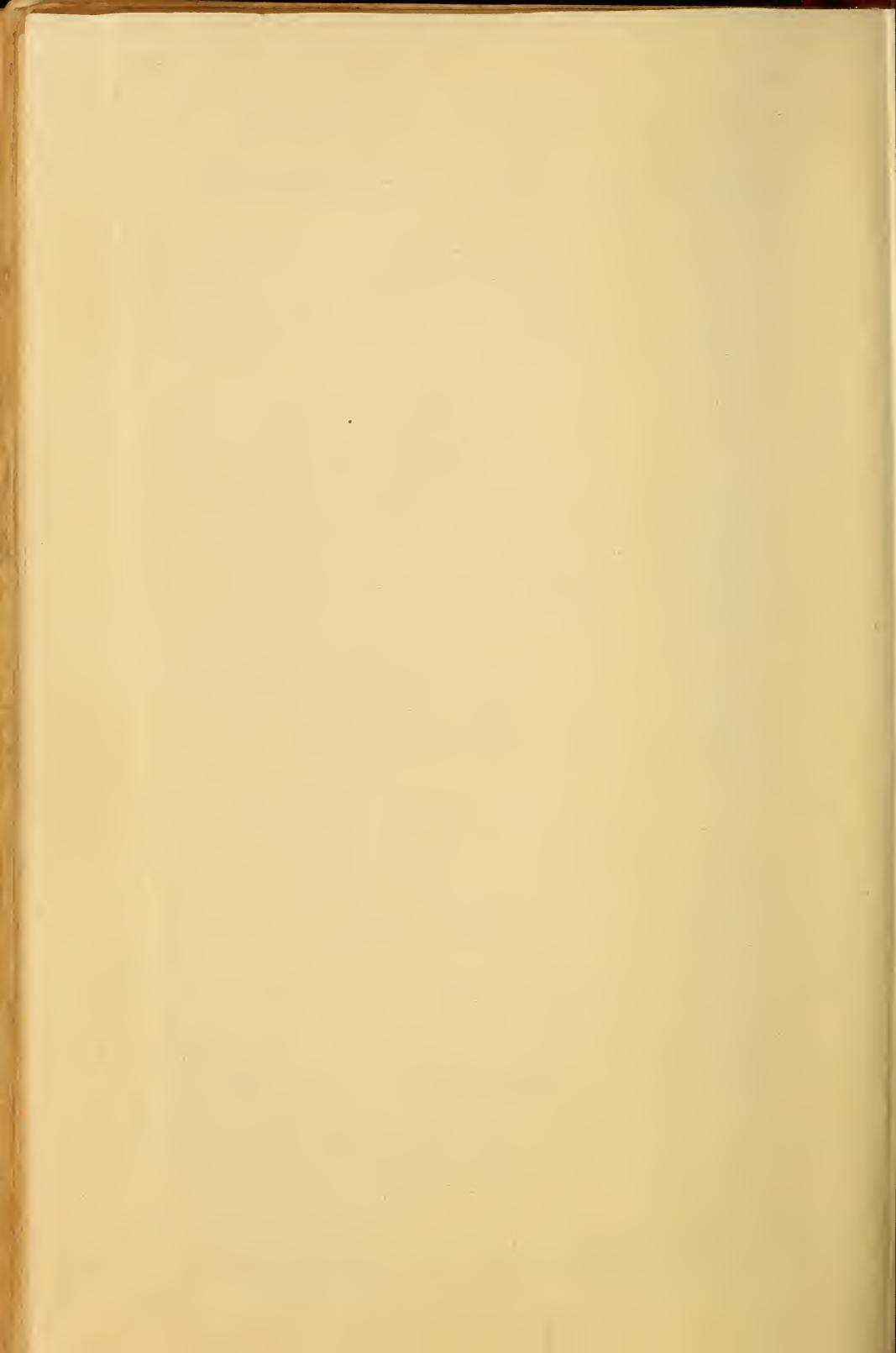
A work of great merit. Well calculated to ground the student in the elements of this language, become so important by the extensive settlement of Germans in this country.

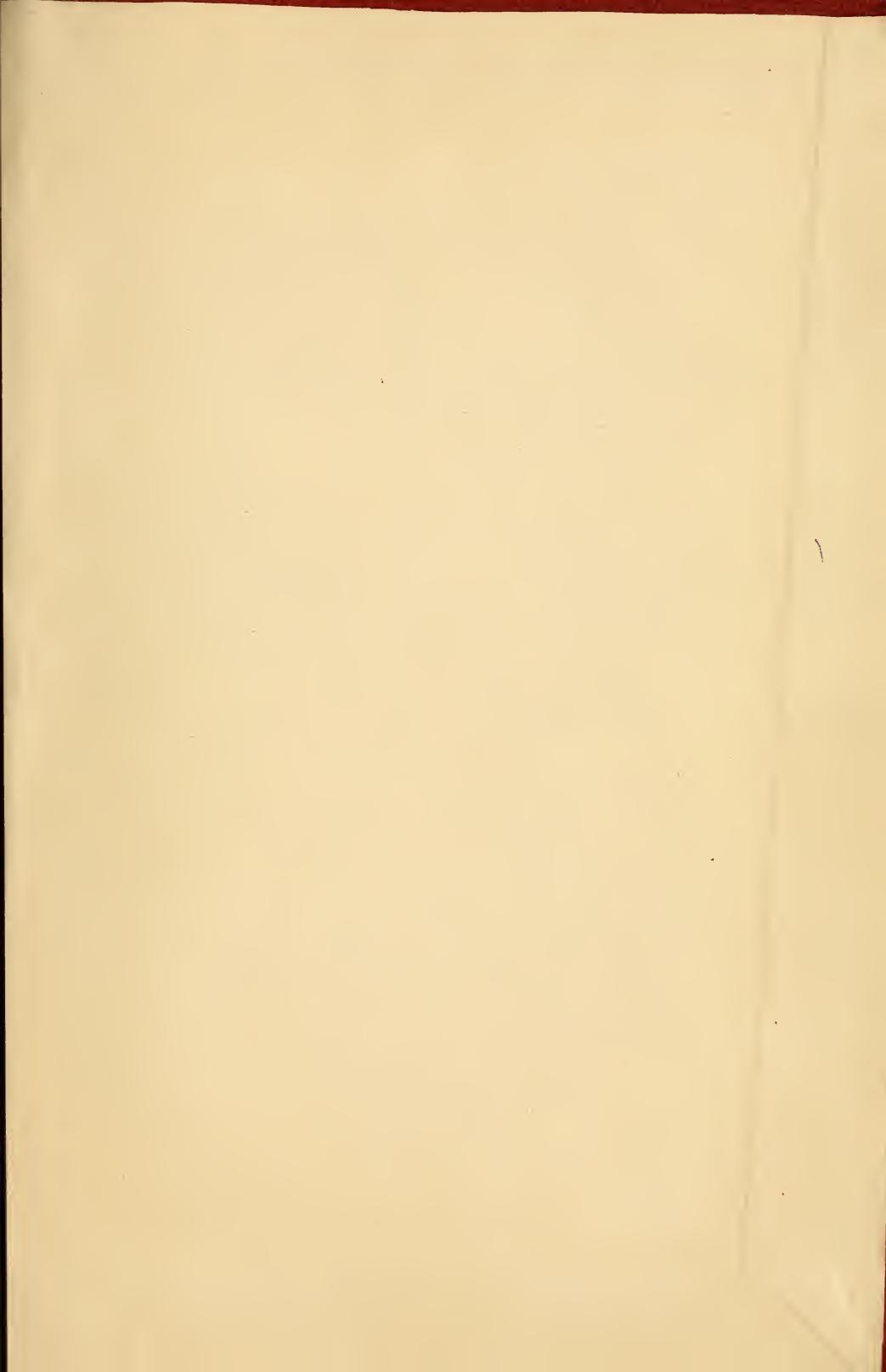
Willard's Historia de los Estados Unidos, . .	2 00
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The History of the United States, translated by Professors Tolon and De Torros, will be found a valuable, instructive, and entertaining reading-book for Spanish classes.

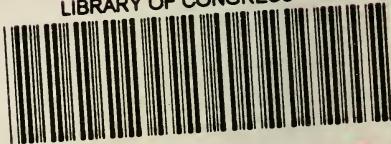
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